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Original Papers
Ceramic Abstracts
and
Activities of the Society

Edward W. Washburn, Editor

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EDITORIAL

CHANGE OF EDITORSHIP

For the second time during the existence of the Journal there is to be a change of editors. Dr. E. W. Washburn now succeeds Mr. Homer F. Staley.

Mr. Staley succeeded Mr. Geo. H. Brown, the first editor of the Journal, and has handled all editorial matters in connection with the publication of Vol. 3. Mr. Staley has been progressive in his policies and during his term of office the departments of Ceramic Abstracts and Society Activities have been included and enlarged.

In giving up his work at the Bureau of Standards in Washington and accepting a commercial position, Mr. Staley finds that the new duties will not permit his carrying on the editorial work of the Journal as heretofore and the Board of Trustees has therefore with regret accepted his resignation.

Dr. Washburn comes to the editorial work thoroughly fitted in every way for the position. For some years, he has been at the head of the Ceramic Department of the University of Illinois, and in this position has established a splendid condition of coöperation between the practical clay workers of Illinois and the technical work of the students of the University. Dr. Washburn ranks high both technically and in his conception of the practical problems of the ceramic industry, and the readers of the Journal may look forward to thoroughly well balanced subject matter covering the various phases of ceramic engineering and production.

L. E. BARRINGER

CERAMIC DECORATIVE PROCESSES DIVISION

The annual meeting at Columbus will be marked, among other things, by the first session of the newly organized *Division on Ceramic Decorative Processes*. The Board of Trustees has appointed Mr. Leon V. Solon as temporary chairman, and Mr. Frederick H. Rhead as temporary secretary for the new division. Both these men are well known in the field of artistic ceramics and there is every prospect of their being able to gather a goodly number of interested persons.

The name chosen for the division may be altered. The endeavor was to make it as broad as possible and yet to confine it to the artistic phases of ceramics. This means more than commercial modeling and decoration as carried on in the factory. It should include those who are working in studios and schools with the object of producing or improving wares and methods designed mainly in the interests of beauty.

Sculptors and architects, designers and decorators, archeologists and critics, should all have a share in the new development, and contributions to the program are expected from them and will be welcomed.

PAPERS FOR THE COLUMBUS MEETING

Authors of papers to be presented at the Columbus meeting of the Society are requested to send their manuscripts to the editor before the meeting, and *as soon as possible*, in order that the March number of the Journal may not be delayed. Manuscripts received before the meeting will be given preference over those received later.

ORIGINAL PAPERS AND DISCUSSIONS

THE NEW FACTORY OF THE MONONGAH GLASS COMPANY

By E. Ward Tillotson*

Historical

About twenty years ago, food packed in glass jars with vacuum-seal tops became an article of commerce. This step was one of great importance to both the food packing industry and the glass industry, not only because of an extension of the uses for glass, but especially because the difficulties which were encountered stimulated the development of mechanical devices which should produce a more uniform and perfect article of glass than was possible by hand production.

For the successful use with the vacuum-seal, the glass tumbler or jar was, and is, required to be well nigh mechanically perfect. The top upon which the cover fits must be of accurate dimensions and not be distorted and, further, must be smooth and without the irregularities caused by "overpressing" or "underpressing" too much or too little glass. This irregularity in the quantity of glass is unavoidably large where glass is gathered by hand, and is further a source of annoyance by reason of the variations in the capacity and weight of the product. One factory, the Rochester Tumbler Co., Rochester, Pa., was able with care to turn out, in quantity, glass containers which met the exacting requirements. However, this was accomplished only by the aid of selected workmen and by exercising scrupulous care, especially in the final inspection of the product.

*Received July 3, 1920.

The superintendent of this factory, Mr. H. L. Heintzelman, who had been responsible for this successful production, clearly foresaw the future growth of this type of glassware and resolved to build a factory primarily to produce glass tumblers from continuous tanks. Associated with Mr. Heintzelman in this industry was Mr. William Moulds, now deceased, General Manager of the Rochester Tumbler Company, and a glass maker of long experience and high ability. Prior to this time, the better grades of glass were made in covered pots. The continuous tank had been in use since 1879 and, subsequent to the introduction of natural gas, had come into favor for the manufacture of window and bottle glass. The production, therefore, of a high grade of "crystal" in continuous tanks marked an important advance in glass technology. It was the result of the use of the best of raw materials and of constant personal attention on the part of men who through years of experience and of constructive observation had evolved an idea typically American and who possessed the courage and energy to carry it to a successful conclusion.

At that time natural gas was established as a fuel for melting glass and accordingly a location for the new enterprise was selected with this as an important consideration. Fairmont, W. Va., was well situated with respect to fuel and to transportation, and, furthermore, was a city in which the workmen would be content to live. Therefore, Fairmont was selected as the site of the new factory and the Monongah Glass Company received its charter under the laws of West Virginia on December 29th, 1903. Construction of the factory was commenced on April 18th, 1904, and the first glass was produced on August 18th of the same year. The buildings were of the cheap frame construction which, until recently, has characterized glass factories, and housed two 12-ton continuous tanks, each having eight rings. The capacity of this factory expanded rapidly: within two years a new factory was built especially to produce blown tumblers and stemware from lead glass. The use of vacuum-seal glass containers for foods increased, and it became evident that hand production not only would be unable to keep pace with the demand; but also, by reason of the special skill required on the part of the workmen, the prospect of a limited number of men of the necessary skill directed

attention to the development of a mechanical device which would take the place of human skill and allow of a production which would not be limited by the personal equation. Accordingly, in 1910, and in coöperation with the Beechnut Packing Company and the engineering firm of Wm. A. Lorenz & Company, Hartford, Conn., the development of a mechanical feeder and an automatic press was commenced. These devices, which are controlled by the Hartford-Fairmont Co.,[1] have during the past two years entirely supplanted the hand-presses at the Monongah Glass Company for the production of packers, tumblers and jars. The feeder has found an increasing usefulness in other factories for the manufacture of both wide and narrow mouthed bottles, milk bottles, lantern chimneys, and incandescent lamp bulbs. At present there are eight feeders installed at Fairmont and about sixty in other factories; the total capacity is 200,000 tons of glassware per annum.

During the development of these devices, they were used in connection with furnaces which already had been built and in factories which had been designed for hand-production. This, while successful, was recognized as being far from the ideal situation. It was determined that a new factory should be built in which all parts should be correlated to bring about the most favorable conditions for the mechanical production of pressed glassware, and it was resolved further that this should be no temporary structure of cheap construction but should be built in accordance with modern factory construction as a permanent house for these newly successful machines. This new factory was constructed during the latter part of 1918 and was put in operation on April 1, 1919. It is designed to contain two 50-ton tanks, each with four Hartford-Fairmont feeders and four Hartford-Fairmont duplex presses. At present, only one tank has been built, the second one waiting on any changes in design or arrangement that may prove advisable. There is also some machinery to be installed, and an auxiliary building for the transformers and for an addition to the machine shop and mold room is planned for the near future.

This new factory, therefore, is worthy of note by reason of its

[1] A company of the State of New York of 1912.

being of expensive[1] and permanent construction, by reason of the high quality of glass produced in the continuous tanks, and by reason of the efficient design and arrangement which allow of mechanical production in the greatest degree. Indeed, the writer considers it a privilege that he has been permitted to secure intimate data with respect to this factory for presentation in THIS JOURNAL. So far as the writer knows, this is the first detailed description of an American glass plant to be made public, and this fact certainly marks a new and laudable attitude on the part of the American glass manufacturer.

The Buildings

The buildings of the new plant of the Monongah Glass Company are of the well known reinforced-concrete type of factory construction. The warehouse and factory, which are adjacent to each other, total 161 ft. 6 in. in width and 270 ft. 10-½ in. in length, and extend in the north and south direction (see figure 1). The

FIG. 1.—The new factory of The Monongah Glass Co. (looking northwest). At the extreme left are buildings of the old plant.

factory, which contains the tanks, presses and leers, is 161 ft. 6 in. by 160 ft. 9 in. and is located at the south end of the warehouse. The factory floor is on a level with the first floor of the

[1] This complete unit represents an investment of between $700,000 and $800,000.

warehouse and in direct communication with it (see figures 2 and 3). The walls of both buildings are described as being 9-in. curtain walls, extending three feet above the floor, the balance of the walls being taken up by windows.

The Warehouse.—The warehouse contains a basement and three floors of the following heights, measured from floor to floor: basement, 13 ft.; first floor, 14 ft.; second floor, 13 ft.; and third floor, 12 to 18 ft. The floors are flat slabs of reinforced concrete and are designed to support a load of 350 pounds per square ft. The surface of the floors are hardened with "Lepidolith" hardener. The columns are cylindrical and form eleven bays of 18 ft. 10 in. centers and ten bays of 16 ft. centers. The building is equipped with "United States" steel sash and ventilators, and the monitor in the roof, which extends lengthwise of the building, is equipped with operating sash. The roof of the warehouse is of reinforced concrete and is finished with Barber's asphalt roofing.

The warehouse contains two freight elevators, 8 ft. by 12 ft. 6 in., which are driven by electric motors, and operate between the basement and the third floor. The main stairway is located in the northeast corner of the building and is of concrete. An additional stairway is provided at the north end of the warehouse near the center, and an outside fire-escape at the northeast corner of the building. Ample toilet accommodations are provided on each floor, and the Fairmont Box Company occupies office rooms on the second and third floors.

The partition between the warehouse and factory on the second floor consists largely of windows which give opportunity for inspection of the factory from this floor, and also allows the heat from the factory to be utilized. The building is heated by direct radiation by steam, which is generated at a central boiler plant located at the northeast end of the factory and which supplies heat for the entire plant. The warehouse is also equipped with adequate water, gas and sewage plumbing, and is protected from fire with the sprinkling system of the General Fire Extinguishing Company. The electric wiring is all contained either in steel conduit embedded in concrete or is supported on the steel structure of the building. Separate panels are provid-

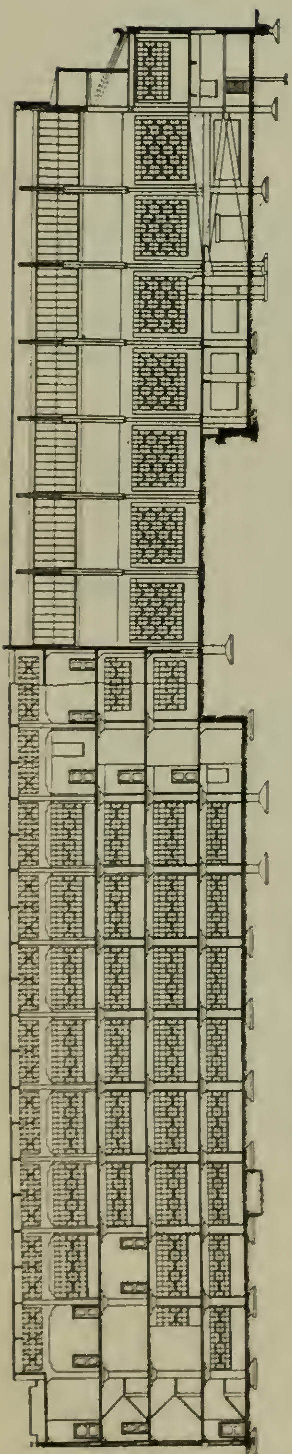

FIG. 2.—Longitudinal section through factory and warehouse.

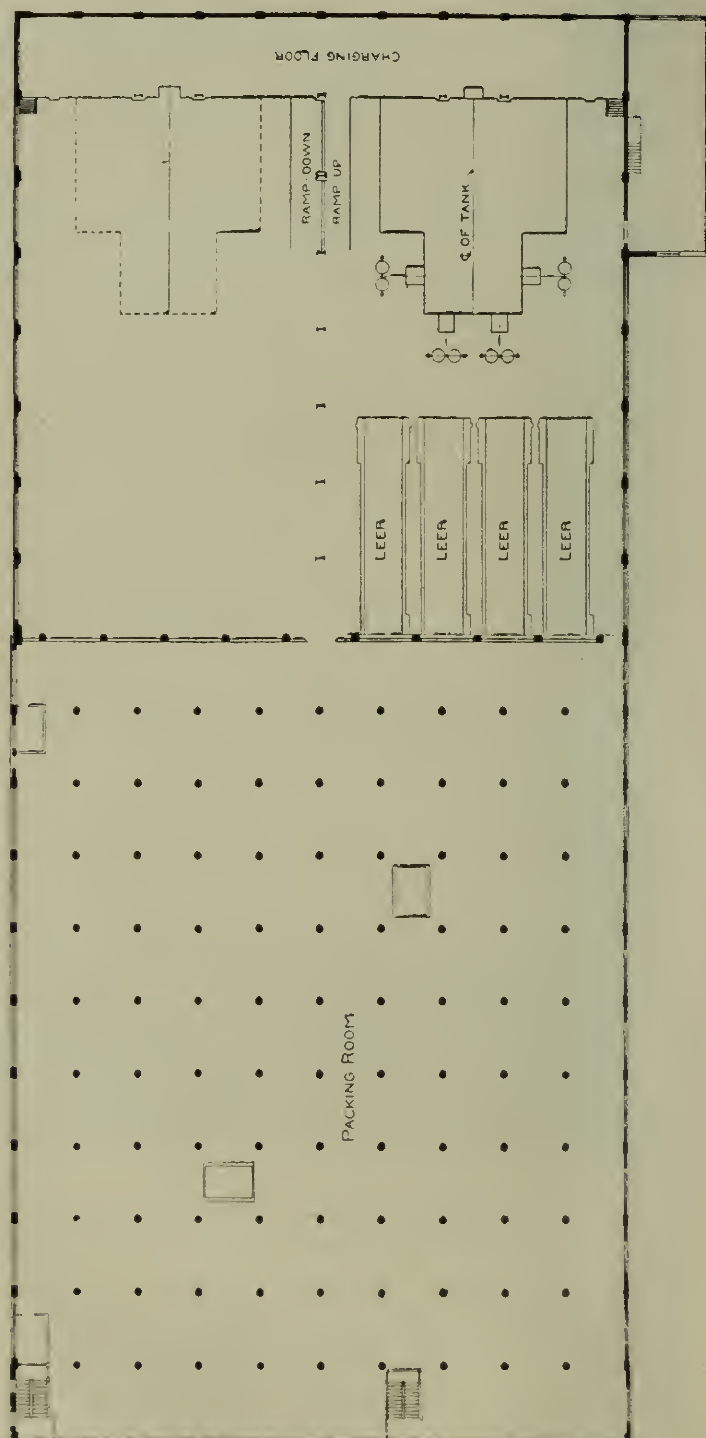

FIG. 3.—First floor.

ed on each floor for light and power. The main transformers consist of three 100-K. V. A. transformers, located in an enclosure in the basement of the compressor room, and are connected with the 2200-volt power mains. It is planned, however, that in the near future an outside substation will be installed which will contain three 250-K. V. A. transformers connected with the 22,000-volt power mains.

Only the first and second floors of this building are used for the warehouse proper. The basement and third floor are largely employed by the Fairmont Box Company for the manufacture of corrugated-fiber board and corrugated-fiber board boxes, in which the glassware is packed for shipment. The board is manufactured in the basement and the boxes are formed on the third floor. From the third floor, the boxes are delivered into chutes, through which they pass to the second floor, and then are placed on roller gravity conveyors, by which they are directed to the desired point. On this floor there are eight hatches, one for each leer. The chutes leading from these hatches are at an angle of about 30°, terminating at the bottom in a horizontal section, about 10 ft. long and directly over the leer. This arrangement, therefore, represents an economy of space and brings the boxes directly to the hands of the "selector," who fills them with glass from the leer.

Scrap chutes of galvanized iron, about 2 ft. by 4 ft. in dimensions, are provided for conveying waste material of the box manufacture from the third floor to the basement. These chutes have openings on each floor.

The Factory.—The factory building contains one floor on a level with the first floor of the warehouse and connected with it, and a basement. The factory basement floor is slightly above the level of the warehouse basement but is not connected with it.

The factory roof is supported by nine steel trusses spanning one-half the width of the building, with a slope of one-half pitch. At the top of each ridge is a steel monitor extending the length of the building with the exception of one bay, which is occupied by the batch conveying system (see figures 1 and 4). Each monitor is equipped with two courses of "United States" top hung sash,

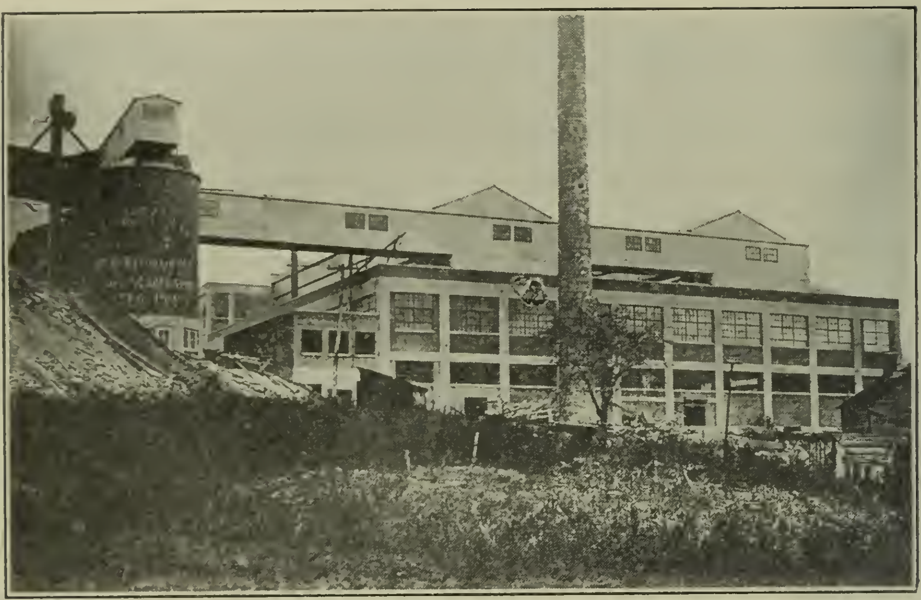

FIG. 4.—Factory building (looking northeast).

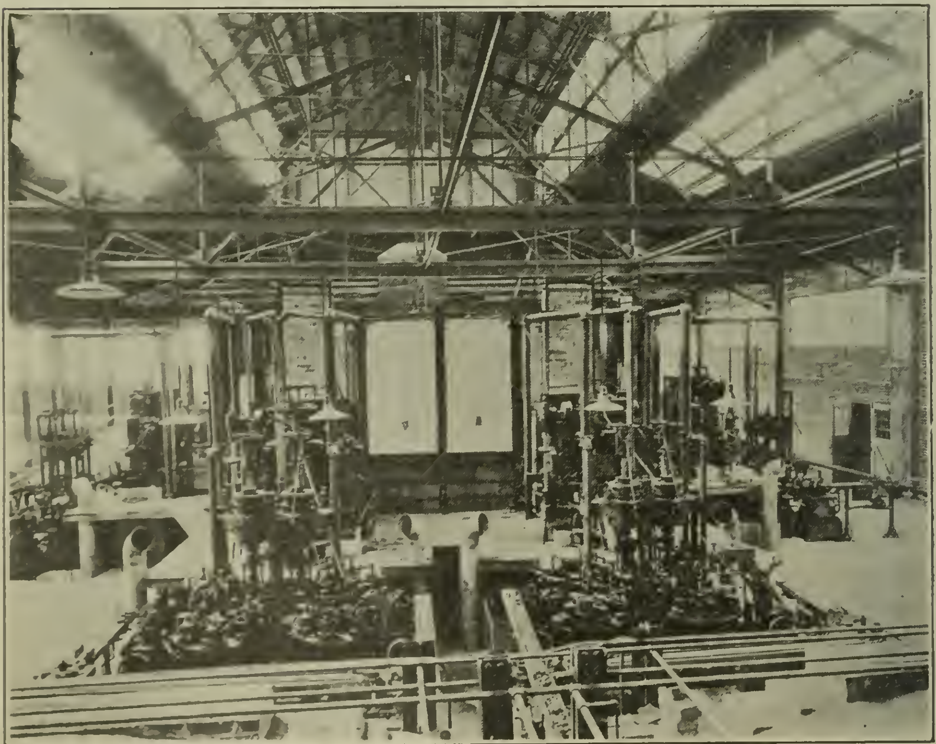

FIG. 5.—Machines.

operable from the factory floor by chains (see figure 5). Extending across the building, on the plant end, is a steel gallery carrying the belt conveyors for bringing the glass batch to the furnace bins. This gallery extends over a bridge to the batch storage-bins just west of the building (see figure 4). The factory roof is of corrugated asbestos sheet roofing supplied by the Keasby & Mattison Company. The gallery also is roofed and sided with the same corrugated material. Directly above the machine presses and above the rear end of the leers are spaces in the roof, 8 ft. by 20 ft., fitted with sheets of corrugated wire glass[1] to match the asbestos roofing (see figures 5 and 6).

At the south end of the basement, extending across the end of the building, is a mezzanine floor, 12 ft. 10 in. wide and 7 ft. above the basement floor. This is connected with the basement floor by a concrete ramp, 8 ft. wide, and with the first floor level by a similar ramp. Extending across the south end of the building, 4 ft. 4 in. above the main floor, is the charging floor which is connected with the main floor by a third ramp. The main floor is built to within two feet of the tank walls and is supported by special columns from the basement to accommodate the machine presses, furnaces, etc.

The factory is designed to accommodate two 50-ton continuous tanks, but at the present time only one of these has been completed. This tank is of the well-known type designed by H. L. Dixon. The melting compartment is 20 by 32 ft. inside and the refining end is 20 by 14 ft.; the walls are 12 in. in thickness. It is equipped with five ports on each side and with regulators for both air and gas. The melting capacity is 50 tons per 24 hours. The one uncommon feature about this tank is its unusual height above the working floor (7 ft. 5 in. from the working floor to the metal line); this was made necessary in order that the feeder and press might be operated conveniently. The metal in the tank is about 41 in. in depth.

On the nose of the tank are two forehearths on 14 ft. centers, which extend 7 ft. 9 in. from the tank wall, and on each side of the furnace at approximately the middle of the working end is also located a similar forehearth. These forehearths are con-

[1] Manufactured by the Pennsylvania Wire Glass Company.

structed of special shaped fire-clay blocks and are insulated with "Nonpareil" cork brick, and each contains one of the Hartford-Fairmont feeding devices. The forehearths are heated by high

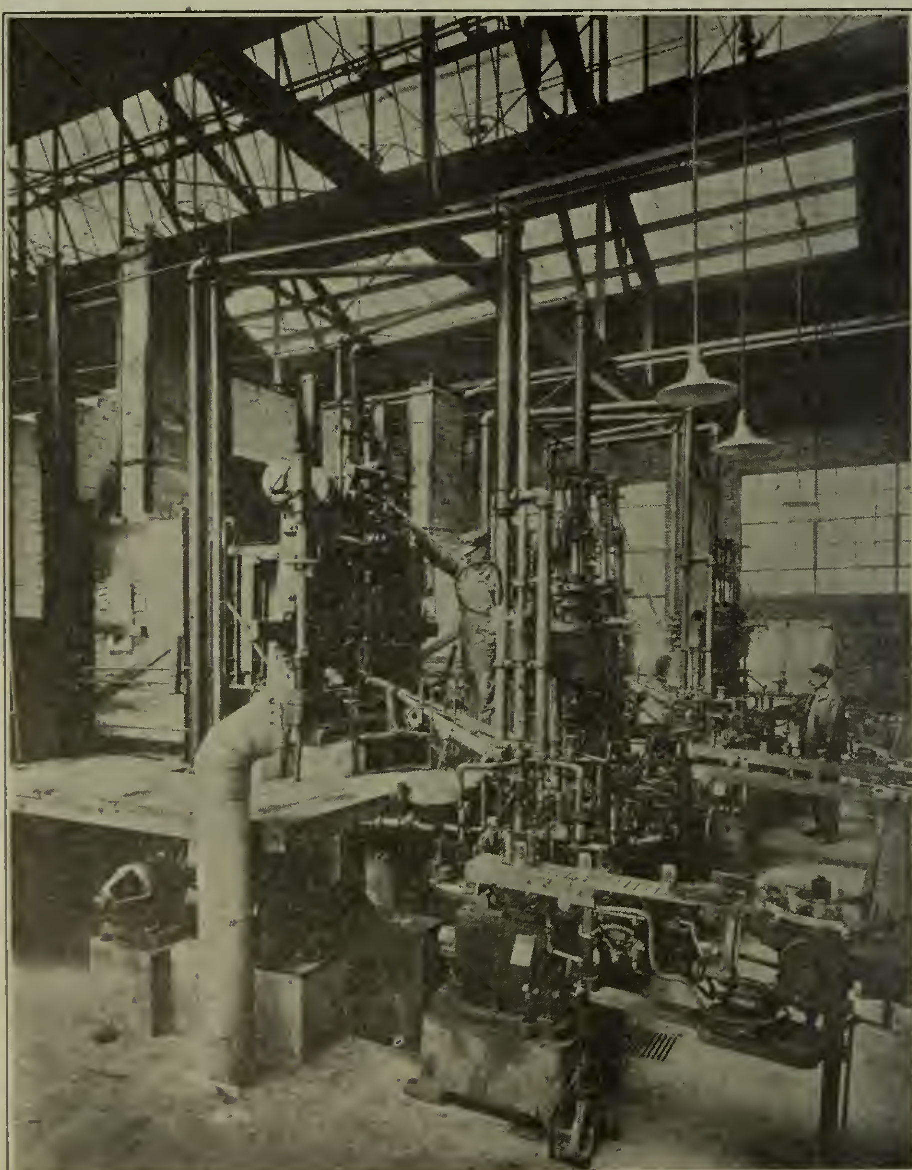

Fig. 6.—Two machines at nose of tank.

pressure (15 to 20 lbs.) natural gas. The tanks are designed to use producer gas and each requires about 210,000 cubic ft. of 125 B.t.u. gas per hour.

The Hardford-Fairmont Feeder

The principal operating feature of the Hartford-Fairmont feeder consists of a moving paddle,[1] which forces a quantity of the molten glass over a fire-clay dam. The glass then flows through an opening in a fire-clay ring, thus forming a "gather" of suitable size and shape for the pressing operation.

Figure 7 shows a longitudinal section of the feeder. *A* represents

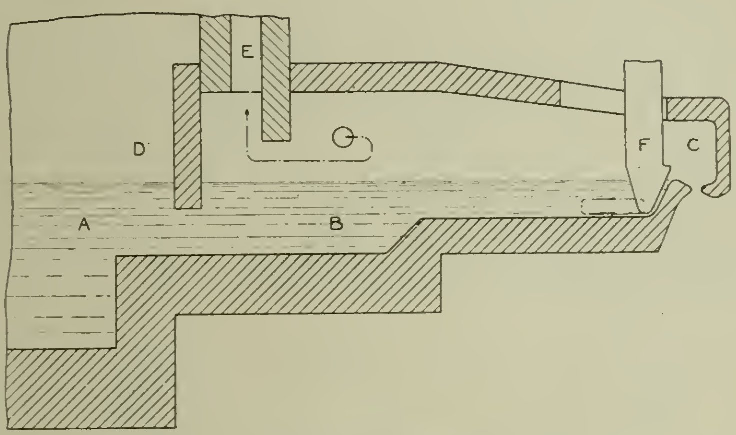

FIG. 7.—Hartford-Fairmont feeder.

the working end of the glass tank. *D* is a fire-clay partition dipping below the level of the glass and acting as a skimmer to remove bubbles or insoluble material floating on the surface of the glass. From *A* the glass flows under *D* and into the chamber *B*, which consists of a channel, 12 in. wide, narrowing to a width of about 6 in. at the extreme end. *F* is the paddle which operates within this channel, forcing a portion of the glass at each stroke into compartment *C*, where it falls through the opening as indicated. A pair of knives operate directly beneath and close to this opening, shearing off each "gather," which falls into a trough and is conveyed to the mold.

[1] See U. S. Pat. 1,328,799, Jan. 20, 1920, Karl E. Peiler;
See also U. S. Pats. 1,277,254, Aug. 27, 1918, Karl E. Peiler;
1,277,255, Aug. 27, 1918, Karl E. Peiler;
1,277,256, Aug. 27, 1918, Karl E. Peiler;
1,324,464, Dec. 9, 1918, Karl E. Peiler;
1,328,799, Jan. 20, 1920, Karl E. Peiler;
1,332,405, Mar. 2, 1920, Karl E. Peiler.

The paddle is driven by a mechanism which is connected directly and synchronized with the press which it feeds. The path traveled by the paddle may be described as that of a distorted ellipse. At the end of each stroke it is raised slightly and then is carried back in a nearly straight line, after which it is lowered and travels forward in a substantially straight line. At all times it dips beneath the surface of the glass, a condition which is necessary in order to prevent the introduction of air bubbles through a churning action. Both the "dip" and the stroke of the paddle may be regulated. The stroke ordinarily varies from four to six inches and is determined by the weight of the article which is to be made. It is, therefore, a permanent adjustment. The dip below the surface of the glass varies from two to four and one-half in., and the distance between the upper and lower path of the paddle is approximately one and one-half in. The quantity of glass delivered by each stroke may be regulated while the machine is in motion by raising or lowering the paddle, thus varying the dip. The provision is necessary in order that the amount of glass discharged may be kept constant in spite of variations in the level of the molten glass and that the effects of unavoidable temperature fluctuations in the channel may be balanced. This is controlled by a hand-wheel within easy reach of the press attendant. The paddle is of fire-clay, about five in. wide and shaped to fit closely the channel at the end of the stroke. The paddle has an average life of two months.

The fire-clay ring through which the glass is discharged and which forms the glass into a shape suitable for pressing, is contained in a metal frame and allows of easy removal and replacement. It has been mentioned that the quantity of glass delivered is determined by the stroke and the dip of the paddle. In extreme cases this may be adjusted to deliver from $^3/_8$ oz. to 42 oz. of glass. In practice, however, the range is between 1 oz. and 32 oz. The life of the glass outlet ring is approximately one month and ten minutes are required for the insertion of a new ring.

The channel *B* is heated by means of high pressure natural gas through burners in the side walls. The products of combustion follow the course indicated by the arrow, passing under the clay baffle and out the flue *E* into the stack. The temperature of

the glass in the nose of the tank (A) is approximately 2050°F. and in the channel (B) is approximately 1950°F. The paddle delivers through the outlet ring C just enough glass for one of the articles which is being pressed. It is necessary, however, to separate the drop so formed from the small amount remaining in the outlet and this is accomplished by two V-shaped knives[1] of carbon steel acting close to the outlet. These knives are actuated by a mechanism connected directly with the rest of the machine, and, of course, are synchronized with it. Their action is almost instantaneous and their V-shape results in eliminating the "shear mark" on the pressed piece. After being severed, the glass drops into a trough inclined at an angle of about 30° from the horizontal. This trough is of metal and is lined with a porous carbonaceous material which is kept moist by a small stream of water. The glass, therefore, slides down the trough upon a film of water vapor without sticking and without showing differential cooling.[2]

Each feeder supplies 2 presses[3] which carry 8 molds each. The trough above mentioned is composed of 3 sections, the upper one of which is pivoted and is caused to swing so that it delivers glass alternately to each of the presses. From the lower section of the trough the glass is delivered into a funnel, which directs it into the mold. Each revolving mold table carries 8 molds. As the table revolves, it halts momentarily at 8 stations, at which the following operations take place:

(1) The glass drops into the mold.
(2) The pressing operation is performed.
(3) and (4) The pressed article is cooling and "setting."

[1] See U. S. Pat. 1,326,460, Dec. 30, 1919, Wm. A. Lorenz.
[2] See U. S. Pat. 1,199,108, Sept. 26, 1916, Karl E. Peiler;
U. S. Pat. 1,264,328, Apr. 30, 1918, Karl E. Peiler;
U. S. Pat. 1,300,180–1, Apr. 8, 1919, Wm. A. Lorenz.
[3] See U. S. Pat. 1,259,280, Mar. 12, 1918, Karl E. Peiler;
U. S. Pat. 1,259,281, Mar. 12, 1918, Karl E. Peiler;
U. S. Pat. 1,291,952, Jan. 21, 1919, Wm. A. Lorenz;
U. S. Pat. 1,292,033, Jan. 21, 1919, Karl E. Peiler;
U. S. Pat. 1,316,550, Sept. 16, 1919, Karl E. Peiler and E. H. Lorenz;
U. S. Pat. 1,331,471, Feb. 17, 1920, Karl E. Peiler and W. A. Lorenz;
U. S. Pat. 1,331,472, Feb. 17, 1920, Karl E. Peiler and E. H. Lorenz.

(5) The article is taken out of the mold.

(6) (7) and (8) The mold is cooled preparatory to receiving the new charge of glass.

At station 8 the mold ring is raised and swung over a gas burner to maintain it at the proper working temperature. The press plungers are operated by compressed air at 40 lb. pressure and exert an estimated pressure of 4000 lb. to the sq. in. This pressure may be regulated by the attendant (through a crank within easy reach; see figures 5 and 6). The plungers are hollow and are water-cooled. It is estimated that the average temperature of the surface of the mold is 600°F. and of the plunger 800°F. The presses and feeder are all driven by a 3-horsepower motor and are all operated from one shaft. In practice, 1 feeder with 2 presses is capable of turning out 44 pieces per minute of 4 oz. in weight, or 36 per minute of 12 oz. in weight. The cost of one unit as described above is approximately $15,000.

The advantages which are claimed for this device consist in an article of more uniform weight, the weight being controllable within 2 per cent; a greater production and full operation during the 24 hours in three shifts, and ware of better quality. At present 60 of these feeders are in operation throughout the country and are employed in the making of bottles, both narrow and wide mouth, bulbs for incandescent lamps, and a variety of other products.

At station 5, the article is removed from the mold by a plunger, operating vertically, which raises the article above the top of the mold. At this point it is seized in a metal frame operating like a pair of hands. This device, which swings in a vertical arc, is actuated by the same mechanism which operates the press. By its action the ware is inverted and placed upon an iron plate and released, and a lever then pushes the article on to the automatic conveyor, which carries it to the leer.

The conveyor which automatically carries the ware to the leer, and also automatically introduces the ware and distributes it in the leer, is the well known mechanism of the Automatic Machinery Company, of Terre Haute, Ind. It is, however, supplemented by features developed by the Hartford-Fairmont Company, which prevent sudden cooling of the glass with the attendant

troubles from chipping and breakage during its course to the leer. The particular addition consists of a tunnel formed of material of low thermal conductivity which is built over the conveyor and through which the ware passes.

The leers are of the Steelman muffle type and were designed by Mr. H. L. Dixon. One leer is provided for each machine. They are 60 ft. long and 10 ft. wide in the clear, and the pan is operated continuously by a variable speed direct-current motor. This speed of the leer pan may be varied from 3-½ in. to 6 in. per minute. The heating end of the leer is 11 ft. 9 in. long and 30 in. high from the pan to the arch. The roof then slopes during a distance of 4 ft. 3 in. to an average height of 10 in. above the pan, and was so designed as to prevent a general distribution of the hot gases throughout the leer by reason of convection currents. The heating end is insulated with "Nonpareil" cork brick and this lagging also extends over two arches of the cooling end. The leers are heated with producer gas. The burners are placed at the sides and below the leer, and the hot gases travel through 9 by 6 in. flues in three up-comers and three down-comers on each side of the leer. The air employed in the burners is heated in a recuperator, through which the hot waste gases pass.

Some modification of the leer has been made to better accommodate it to the use of producer gas and to adapt it for the automatic devices. One of these is an extra burner which has been located under the pan at the filling end to maintain the desired temperature at this point. Each leer consumes about 12,500 cu. ft. of producer gas per hour.

The producer gas, which is furnished by the Monongahela Valley Traction Company, is manufactured in a system of Lymn producers located near the north end of the plant. It is conducted to the factory through a 33-in. riveted pipe of $^{3}/_{16}$-in. steel. This main pipe line is about 1100 ft. in length and from the end a 24 in. spiral riveted pipe leads to the furnace and a 12-in. pipe brings the gas to the leers.

The gas reversing valve is the Wellman-Seaver-Morgan 30-in. Forter valve. The air reversing valve is of the Siemen's type.

The average composition of the producer gas is as follows:

Carbon dioxide........	15–16	per cent
Carbon monoxide......	6–8	per cent
Hydrogen.............	18–21	per cent
Oxygen...............	0.7–0.8	per cent
Methane..............	2.5–4.0	per cent
Unsaturated..........	0.6–0.9	per cent

The average calorific value of this gas is 125 B.t.u. It is received at the factory at a pressure of 3-½ oz. and at a temperature of about 100°F.

Air for chilling the pressed ware in the molds and for cooling the feeder paddle and blowing out chips from the molds is provided at 3–½ lb. pressure. This is supplied by three General Electric centrifugal compressors with a total capacity of 8 machine presses, with a No. 8 Sturtevant blower held in reserve. The ducts carrying this air are of heavy galvanized pipe and are all underground.

For operating the presses and the automatic unloading devices, air is supplied at 40 lb. pressure. This is provided by one Ingersoll-Rand compressor, belted type, 17 in. by 12 in., and operated by a 70 horsepower motor. It is planned to install a second unit of the same type and also two Ingersoll-Rand compressors, 14 in. by 10 in., of the same type, and each operated by 40 horsepower motors. The high pressure air is carried through overhead steel pipes.

These blowers are located in an auxiliary room of two stories on the south west corner of the factory, 61 ft. 1–½ in. by 21 ft. 3 in. in dimension.

The water system which provides for the cooling of the presses and the plungers of the machine presses is the city water which is raised to 75 lb. pressure by a centrifugal pump. This cooling water is collected and stored in the 2000-gallon reservoir for later use. It is planned that a spray system be installed for cooling this water.

The air used in cooling the tanks and men is supplied by the 150-in. Garden City, three-fourths housed bottom-discharge blower, operated by a 50 horsepower motor at 300 R.P.M. From this blower the air passes into an undergound duct of concrete, 5 ft. by 4 ft. in cross-section. Branch ducts at an angle of about

45° to the main duct lead to the machine presses and the furnace. The air duct leading to the furnace is 36 in. sq. and branches into the working end of the furnace in two ducts, 24 in. square, extending underground on both sides of the furnace. From these ducts 10 in. galvanized pipes conduct the air to the vent pipes of the furnace. These vent pipes are divided into 3 closed-end sections of 2 courses each. Each section is 9 ft. 6 in. long, of reinforced galvanized iron, carrying a slot varying in width from $^1/_4$ in. at the center to $^3/_8$ in. at the end of the section (see figure 8).

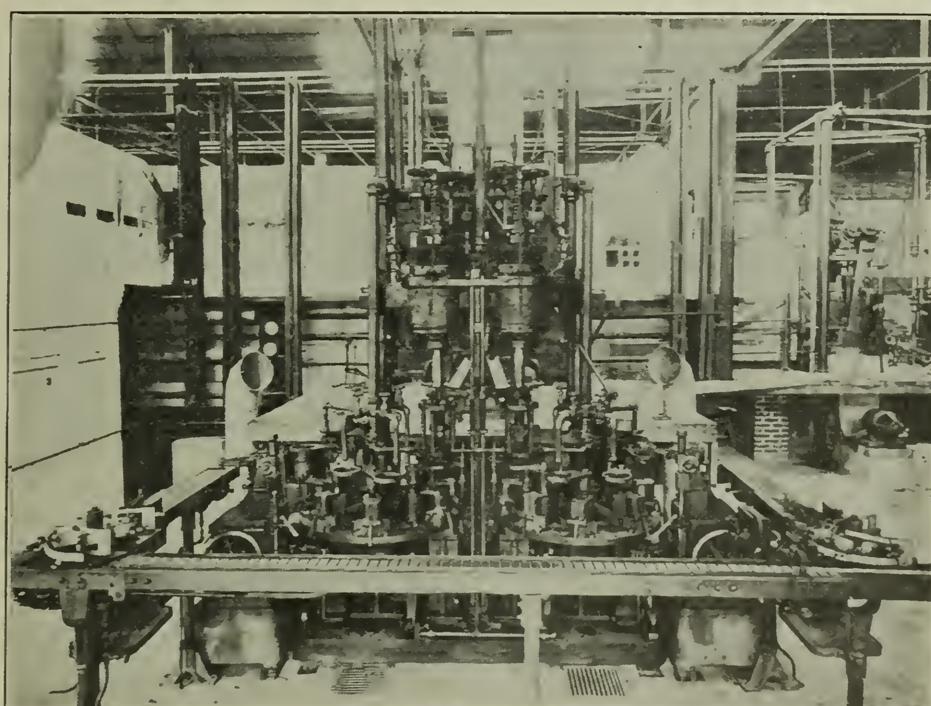

FIG. 8.—Machine at side of tank.

The vertical risers are of 10-in. steel pipe from the concrete duct to a height of 4 ft. above the floor, to protect the system in case of an emergency.

The air is supplied at a pressure of from 2–½ to 3 in. of water. The underground concrete duct bottom is built over a uniform gradient from the extreme end to the fan bed, so that the water will flow toward the fan and through the trap to the sewer. Each vertical 10 ft. duct is equipped with a blast-gate valve.

To provide for the comfort of the workman, each machine system is equipped with 6 of these 10-in. pipes (see figures 5, 6 and 8), connected with the air system. Four of these terminate in cast-iron floor grids, and two of them are carried above the feeder platform and are provided with "turn-heads" which may be turned in any direction.

The Batch System

Opposite the south end of the factory and to the west are 5 storage bins near the railroad track. They are 20 ft. inside diameter and 28 ft. high to the bottom of the roof cone and each is designed to hold 10 carloads of materials. The walls, which are 6 in. thick and are constructed of Wiederholdt patent clay tile, have lateral reinforcements in every 12-in. course and vertical reinforcements on 21-in. centers. The reinforcing rods are embedded in concrete which fills the hollows of the concrete block. The conical roof is supported on steel rafters covered by "hyrib" reinforcing and is of concrete 3 in. in thickness. The slope is about 30°. At the top is an opening two ft. in diameter, through which the material is delivered to the bins. The bins are supported on a reinforced concrete foundation capable of supporting a load of 3,000 lb. per sq. ft.

Bins 1 and 2 are used for the storage of sand, and bins 4 and 5 for soda ash. The central bin, 3, is built with 3 compartments, for cullet, lime and the mixed batch, respectively.

The raw materials are unloaded from the car by a Clark shovel into a hopper adjacent to the central bin. From this hopper the material passes through a chute into the elevator boot, and from there it is lifted to a point about 30 ft. above the storage bin, where it is delivered into a chute which directs it on to a 20-in. shuttle belt conveyor (see figures. 1 and 4). This conveyor is protected by a steel gallery extending the whole length of the bin system. The belt conveyor is reversible and is one-half the length of the gallery, so that any bin may be filled from it.

The elevator is of the belt-bucket type equipped with 10 in. by 6 in. buckets and is used for elevating both the raw materials and the mixed batch. At the head of the elevator is a 2-way

gate for discharging the material to the main conveyor or to the shuttle conveyor.

Extending westward from the storage bins is a second gallery of wood, 280 ft. long, which supplies 4 furnaces in the old factory building. This has a 16-in. belt working on 265-ft. centers, and the material is discharged from it by a mechanical tripper.

On the east side of the central storage bin is located a second elevator which carries the mixed batch to a 16-in. belt conveyor in the steel gallery which leads to the new factory.

Nine ft. two in. below the bin floor is the mixing floor. This extends the entire length of the bin system and is equipped with a 4 ft. gauge track, which carries the weighing and mixing car.[1] The raw materials are discharged into the weighing car through duplex gates in the bottom of each bin. The car is of two tons capacity. After mixing, the batch is discharged through track hoppers into the central bin and then is conveyed by a horizontal screw conveyor into either elevator. The car is driven electrically by the 15-horsepower motor for driving the mixing drum, which is 6 ft. in diameter and 4 ft. long.

Two batch bins,[2] which are located over the furnaces and from which the batch is charged into the tanks, are 9 ft. 3 in. square and 11 ft. in effective height. Each contains a 24-hour supply of batch for its furnace. The bins are provided with a pyramidal cover of 45° slope, and the bottom slopes three ways at about 45°. The bins are constructed of $^1/_4$-in. steel and the bottoms are heavily ribbed with angle iron and reinforced with stay bolts. The bins are suspended from the steel structure of the building.

The Batch.—The batch employed in this factory is as follows:

Sand	2250 pounds
Soda	900 pounds
Lime	240 pounds

In addition, there is added a small quantity of a selenium-cobalt decolorizer which has been worked out to meet conditions prevailing in this factory.

[1] This equipment as well as the elevators and belt conveyors was furnished by the Stephens-Adamson Company.

[2] These bins were furnished by the Moss Iron Works, Wheeling, W. Va.

The sand is from Berkley Springs, W. Va., and carries about 0.07% of iron. The lime is from Seneca County, Ohio, and is a highly dolomitic lime; it is used in the burned and ground condition. The soda is the usual dense 58 per cent ash.

Proofs are taken twice each day at both the working and melting ends. The temperatures maintained in the tank are somewhat dependent upon the amount of glass being worked, but on an average are about 2250° F. at the melting end and 2050° F. at the working end. The leers are maintained at about 1000° F., but this temperature is somewhat dependent upon the size of the ware going through.

The Stacks

Each furnace is equipped with the well known stack constructed by the Weiderholdt Construction Company, of St. Louis. These stacks are 5 ft. in internal diameter and 110 ft. high. The first 60 ft. is lined with fire-brick. The stacks are constructed of the patent hollow tile reinforced with ½ in. horizontal steel rings in each 10-in. course and with 1 in. reinforcing rods on 21-in. centers from top to bottom. At the base, these vertical reinforcing rods spread outwards, like the roots of a tree, in a concrete base. The base is of concrete, 16 ft. square, and rests on a secure shale foundation. It is 8 ft. in depth.

Each leer has a separate 24-in. steel stack lined with fire-brick, reaching above the roof of the factory. They are, therefore, about 35 ft. in height.

The Laboratory

The laboratory is located on the second floor of the warehouse building, adjacent to the factory. It, therefore, commands, through the windows in the partition wall, a view of the interior of the factory building. The laboratory is approximately 30 ft. by 60 ft. and is equipped with materials and apparatus for analytical and control work. Within the laboratory also are recording pyrometers connected with thermocouples in the furnaces and leers. Each furnace contains a platinum-platinum rhodium couple in the melting end and one in the refining end. Each leer is equipped with a base-metal couple[1] in the hot end of the leer.

[1] These couples are all compensated for the cold junction and were furnished by the Brown Instrument Company.

Behind the furnace on the charging floor there are indicating instruments for the convenience of the furnace man, and there are also indicating instruments by the leers. Behind the furnace there is installed a Frink recording draught gauge, and on the main gas line a pressure gauge for the convenience of the furnace man.

In the laboratory raw materials are subjected continually to chemical control, the lime especially being given close attention.

Selection and Packing of the Ware

At the cold end of the leer the ware is subjected to a most searching inspection. By reason of the fact that this ware is used in connection with vacuum sealed tops, it is necessary that every piece shall be mechanically perfect. Gauge rings therefore are provided, to which each piece must conform.

Samples also are taken every two or three hours and examined in the scleroscope for strains resulting from imperfect annealing. Similar samples also are tested by immersion in boiling water, and, when thoroughly heated, by plunging into cold water. All ware showing defects such as blisters, seeds, mold marks, plunger marks, over or under pressing, checks, chips and leer marks, is rejected summarily and is returned to the cullet bin. To facilitate the handling of this cullet there is provided a 4-ft. concrete duct extending across the selecting end of the leer in which a belt conveyor will be installed, which will carry the cullet to the second conveyor extending the length of the plant, and conveying the cullet to a receiving bin in the factory.

The products of this factory consist of a standard line of "packers", such as "jellies", "peanut butters", "mustards", etc., with an average range of capacity from 4–$^1/_4$ oz. to 16 oz. The ware is placed in corrugated boxes at the annealing end of the leer, and, with the aid of platforms and elevating trucks, is put in storage or is loaded into cars. Each box contains from one to three dozen pieces, depending upon the size of the pieces, and about ten thousand boxes[1] are packed per day.

[1] This corresponds to about 3 carloads, with an average of 2500 to 4000 boxes per car.

Summary

This new factory, constructed in 1918–19, is worthy of note by reason of its expensive (7 to 8 hundred thousand dollars per unit) and permanent construction, by reason of the high quality of glass produced in continuous tanks, and by reason of its efficient design and arrangement and the extensive employment of mechanical devices throughout. This paper gives a detailed description of the factory under the following headings: Historical; Buildings, Warehouse, and Factory; The Hardford - Fairmont Feeder with description operation; The Batch System and the Batch; The Stacks; The Laboratory; and Selecting and Packing the Ware.

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Notice—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

THE EFFECT OF GLAZE COMPOSITION ON THE CRAZING OF TERRA COTTA[1]

By E. C. Hill

The occurrence of crazing on terra cotta is due primarily to the composition of the body, engobe and glaze used. If the compositions used are such that crazing may result, the probability of crazing occurring will be increased by rapid cooling, immature firing and applying the glaze and engobe in a heavy coat. These conditions may be considered of secondary importance however, and if the compositions of the body, glaze and engobe are properly proportioned, these conditions will not cause crazing.

The composition of the body has a considerable influence on the occurrence of crazing. It has been found, in testing clays for use in a terra cotta body that the fat, plastic clays are generally more likely to produce crazing than the less plastic, more sandy ones. The very sandy clays have been found to produce shivering. A certain amount of fat, plastic clay is essential in a terra cotta body. The varied requirements of a good body, however, are such that it would seem poor practice to depend on changing the composition of the body to any extent to control crazing; and whatever changes are necessary to prevent crazing should be made in the englobe and glaze.

The composition of the engobe also has a considerable influence on the occurrence of the crazing. Stull,[2] in an investigation of the properties of enamel brick slips, covered a wide field of compositions and found quite definite relations between the composition of engobes and the occurrence of crazing. Briefly, his conclusions regarding crazing may be stated as follows. A high content of flint in the engobe causes crazing and it may be overcome by substituting clay or feldspar for flint, the former being the more effective. A high content of clay overcomes crazing in the engobe, but causes the glaze applied over it to craze. Substituting

[1] Received February 27, 1920.

[2] *Trans. Amer. Ceram. Soc.*, **12**, 711.

feldspar or flint for clay, reduces crazing in the glaze. It is evident then that the composition of the engobe should be such that there will no tendency for it to craze itself, or cause the glaze applied over it to craze.

The object of the work undertaken in this study was to determine the effect of the composition of the glaze on the tendency to craze, and, as far as possible to determine whether each component as it was added to the glaze, tended to produce or overcome crazing.

Experimental

The body used was composed of equal parts of fat plastic clay that had shown a tendency to produce crazing and one which might be considered medium in this respect. The body contained 35% grog. The trials, 8 by 8 by 2 in., with a heavy egg and dart ornament on the side, were pressed from this body. When dry, the test pieces were sprayed with the engobe regularly used and over this a heavy coat of glaze. They were fired in a small 6 ft. test kiln to cone 5½ in 40 hours and cooled in about the same time. Two burns were made and three trials of each glaze were fired in each burn. The composition of the body, the thick coat of glaze and the rapid cooling were depended upon to produce crazing in those trials where that tendency existed.

In a study of the effect of glaze composition on the fusibility[1] made by the writer the most fusible glaze produced was:

0.40 K_2O		
.30 CaO	0.45, Al_2O_3	3.25 SiO_2
.30 ZnO		.10 SnO_2

It was decided to use this glaze as a basis for this study, but to introduce 0.10 eq. MgO and 0.20 eq. BaO in the RO at the expense of the other RO elements, keeping the clay and flint the same (0.05 eq. clay, 0.75 eq. flint). The formula of the glaze used as a base was:

	0.28 K_2O		
	.21 CaO		
(X)	.21 ZnO	0.33, Al_2O_3	2.53 SiO_2
	.10 MgO		.10 SnO_2
	.20 BaO		

[1] *Jour. Amer. Ceram. Soc.*, 3, 13.

The molecular formulas of the various glazes tested for crazing are shown by the series that follows. Maine feldspar was used and the clay was made up of equal parts of Georgia kaolin and Tennessee ball. All glazes contain 0.05 eq. clay and 0.75 eq. flint.

SERIES A—FELDSPAR ADDITION

	1	2	3 = X	4	5
K_2O	0.08	0.18	0.28	0.38	0.48
CaO	.268	.239	.21	.181	.152
ZnO	.268	.239	.21	.181	.152
MgO	.128	.114	.10	.086	.072
BaO	.256	.228	.20	.172	.144
SnO_2	.10	.10	.10	.10	.10
Al_2O_3	.13	.23	.33	.43	.53
SiO_2	1.33	1.93	2.53	3.13	3.73

A1 has a dull mat surface, but is matured. When drawn from the kiln, A1 was badly crazed, A2 and A3 slightly crazed and A4 and A5 sound. On weathering nine months A2, A3, A4 and A5 crazed slightly and there is not a great difference between them.

Additions of Feldspar within the limits of this study does not have a great effect on the crazing. A1 shows the greatest crazing but further additions of feldspar do not show a decided tendency to overcome crazing, although it does act in this way to some extent:

SERIES B—CaO ADDITION

	1	2	3 = X	4	5
K_2O	0.355	0.315	0.28	0.246	0.209
CaO	...	.11	.21	.31	.41
ZnO	.266	.236	.21	.183	.157
MgO	.126	.112	.10	.087	.075
BaO	.252	.244	.20	.174	.15
SnO_2	.10	.10	.10	.10	.10
Al_2O_3	.405	.365	.33	.296	.259
SiO_2	2.98	2.74	2.53	2.33	2.10

B1 is a dull mat, but is matured. When drawn from the kiln B1 was sound, B2 and B3 slightly crazed, B4 shows medium crazing and B5 is badly crazed. On weathering, B1 remained, sound.

Increase of whiting increases crazing with each addition in this study.

SERIES C—ZnO ADDITION

	1	2	3 = X	4	5
K_2O	0.355	0.315	0.28	0.246	0.209
CaO	.266	.236	.21	.183	.157
ZnO	...	.11	.21	.31	.41
MgO	.126	.112	.10	.087	.075
BaO	.252	.224	.20	.174	.150
SnO_2	.10	.10	.10	.10	.10
Al_2O_3	.405	.365	.33	.296	.259
SiO_2	2.98	2.74	2.53	2.33	2.10

When drawn from the kiln, C1 shows medium crazing, C2 and C3 are slightly crazed, and C4 and C5 are sound. On weathering, C1 and C2 showed bad crazing; C3 and C4 are slightly crazed and C5 sound.

Increase of ZnO tends to overcome crazing with each addition.

SERIES D—MgO ADDITION (FROM MAGNESIUM CARBONATE)

	1	2 = X	3	4	5
K_2O	0.311	0.28	0.249	0.218	0.187
CaO	.233	.21	.187	.163	.14
ZnO	.233	.21—	.187	.163	.14
MgO	.0	.10	.20	.30	.40
BaO	.222	.20	.178	.156	.133
SnO_2	.10	.10	.10	.10	.10
Al_2O_3	.361	.33	.299	.268	.237
SiO_2	2.72	2.55	2.34	2.16	1.97

D4 is a dull mat but matured D5 is a trifle immature. When drawn from the kiln, D1 and D2 were slightly crazed, D3 shows medium crazing and D4 and D5 shows bad, fine-mesh, crazing. On weathering, D1 and D2 are slightly crazed and D3, D4 and D5 are badly crazed.

Increase of MgO tends to produce crazing with each addition.

SERIES E—BaO ADDITION AND F—SnO_2 ADDITION

	1	2	3 = X	4	5	F — 2	F — 3
K_2O	0.35	0.315	0.28	0.245	0.21	0.28	0.28
CaO	.262	.236	.21	.183	.157	.21	.21
ZnO	.125	.112	.10	.087	.075	.10	.10
BaO	.0	.10	.20	.30—	.40	.20	.20
SnO_2	.10	.10	.10	.10	.10	.20	.30
Al_2O_3	.40	.365	.33	.295	.26	.33	.33
SiO_2	2.95	2.74	2.53	2.32	2.11	2.53	2.53

When drawn from kiln, E1, E2 and E3 were slightly crazed. E4 showed medium crazing and E5 was badly crazed. On weathering, crazing increased in all the series and E4 and E5 are badly crazed.

Increase of BaO tends to produce crazing with each addition.

F1 and F2 were slightly crazed, but there is practically no difference between them.

Increase of SnO_2 does not affect the tendency to craze in this study, where the limits of composition were from 0.10 to 0.30 eq.

Series G—H—I—J—Clay and Flint Variations

In these series the Ro is the same as that of the base glaze "X." The clay and flint were varied as follows:

	Eq. Flint				
	1	2	3	4	5
Series G—0.05 eq. clay.......	0.50	0.75	1.00	1.25	1.50
Series H— .10 eq. clay.......	.50	.75	.00	.25	.50
Series I— .15 eq. clay.......	.50	.75	.00	.25	.50
Series J— .20 eq. clay.......	.50	.75	.00	.25	.50

When drawn from the kiln, G1, G2 and G3 were slightly crazed. After weathering six months, no crazing developed in any other glazes in the series of composition shown above. The trials were then re-fired under the same conditions as the original burns to ascertain if any further crazing could be produced by re-firing, but none developed.

Increase of clay decreases crazing with each addition.

The crazing developed on G1, G2 and G3 was very slight and there was practically no difference between them. The fact that the three low flint glazes of the low clay series crazed very slightly, while the two higher flint glazes were sound, shows that what ever influence flint has on crazing is toward overcoming it. Nevertheless, in this study, the effect of flint on the crazing is slight.

Summary

Comparing the effects of equal molecular additions of the various components of the glazes in this study, it was found that ZnO and feldspar overcome crazing, ZnO being the more effective. MgO, BaO and CaO tend to produce crazing, MgO having the

greatest tendency and the effect of BaO being somewhat greater than that of CaO. SnO_2 has no effect on the crazing.

Increase of clay is more effective in overcoming crazing than any other changes that can be made in the glaze formula. Addition of small amounts of clay are more effective in overcoming crazing than much larger additions or substitutions of the other components.

Increase of flint (per molecular equivalent) is less effective in overcoming crazing than increase of either clay, ZnO or feldspar, although, generally, considerable more flint than clay or ZnO can be added without appreciably changing the maturing point of the glaze. In many cases, increase of flint will not overcome crazing in a glaze.

CONKLING-ARMSTRONG TERRA COTTA COMPANY
PHILADELPHIA, PA.

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

Discussion

PROF. C. F. BINNS: I do not find that Mr. Hill gives the composition of the feldspar he uses. He appears to calculate it on the theoretical basis of purity. This does not correspond with my experience. No one of the commercial feldspars shows a potash content of over 14 per cent, and I think that this should be considered in the use of the material.

The conclusion that magnesium, barium and calcium tend to produce crazing in the order given does not accord with my experience in other lines. In the use of magnesium in a glaze my difficulty has been to prevent shivering, and I am of the opinion that the reason why Mr. Hill finds crazing is that the glazes are immature. This, of course, does not effect his result, inasmuch as, under the conditions he shows, magnesia on account of its infusibility may tend to increase crazing.

I suggest this possible cause in order to account for the discrepancy in these conclusions and those usually accepted.

AUTHOR'S CLOSURE: Referring to the criticism of Prof. Binns that feldspar should not be calculated as the theoretically pure material, I would say that this procedure can only be justified as a matter of expediency, as it was desired to standardize the

formulas and results in this study with that of those made previously along the same lines.

In regard to the effect of MgO on this type of glaze, I would say that my experience has been that it does tend to produce crazing. In this study, the effect of the MgO additions was quite marked in this respect. The source of the MgO was "heavy" magnesium carbonate. The same series of glazes were made with steatite as the source of the MgO, with a like result.

All of the glazes containing MgO were well matured with the exception of the one containing 0.40 eq. MgO, the extreme of the series. I cannot agree with the suggestion of Prof. Binns that the glazes containing MgO crazed because they were immature. The immature glazes in this study, with the one exception, were those high in clay, all of which were without crazing.

In this type of glaze, any addition of MgO makes the glaze less fusible. In other types, particularly, those fired at higher temperatures, MgO might become active as a flux and possibly have an effect on crazing just the opposite from that shown in this study. I suggest this as a possible reason why Prof. Binns' experience with regard to the effect of MgO is contrary to mine.

A STUDY OF SPALLING

By Raymond M. Howe and Robert F. Ferguson

Part I.—Definition and Tests for Spalling

When fire-clay brick are subjected to repeated temperature changes, or to unequally distributed or excessive stresses (in arches) pieces become loosened and the fire-brick are said to spall.

The preceding statement is the generally accepted conception of spalling. The "pinching" of arch-brick is due to improper furnace design and this factor is generally disregarded in testing; hence the various tests involve repeated heating and cooling of the specimens. At certain laboratories the fire-brick are placed in the hearth of the furnace and are heated throughout; at others they are placed in the door of the furnace and are heated on one end only.[1] After the specimens have become properly heated they are cooled either by placing in the open air, by partially or totally immersing in water, or by subjecting to a blast of cold air.

It was not deemed advisable, however, to accept any one of these tests as a temporary laboratory standard without conducting a few preliminary trials. Therefore, batches of fire-brick were secured from four manufacturing centers and were subjected to comparative tests.

The general characteristics of these four brands are given in table 1.

Table 1—Physical Properties of Fire-brick T, S, L and D

Brand	Per cent porosity	Total end crushing strength	Fusion point in cones	Per cent compression in 1350° C load test	Permanent linear change after reheating 5 hours at 1400° C
T	24.9	2,220	32	5.1	1.1% contraction
S	17.4	5,846	32–33	4	8 expansion
L	24.9	4,235	29	3.2	0.1 contraction
D	28.2	1,890	30	0.2	1 contraction

[1] Nesbitt and Bell, *Proc. Am. Soc. Testing Materials*, 16, 369 (1916).

After the necessary preparation, all of the specimens were heated on one end for one hour at 950°C. One-half of these were cooled by immersing to a depth of five inches for three minutes in 1.5 gallons of cold water. They were allowed to air-dry for five minutes and the process was repeated. The other half of the lot was cooled by subjecting the hot end to an air-blast from the 2.5 inch opening of a 1.25 H. P. centrifugal blower.

The results of these tests are given in table 2 and are shown graphically in figures 1 and 2. The loss of weight is taken as the criterion, and it is evident that both methods place the bricks in the same relative order, although the more severe water-cooling method does not give the finer distinction secured by cooling in air.

Since the two procedures placed the four brands in the same relative order, the water-cooling method was considered the better because of its greater rapidity. Consequently, the following test was finally adopted as a temporary standard:

"The dry test specimen is weighed in grams and placed in the door of a furnace operating at 1300–1350°C, care being exercised to prevent the direct heating of more than the 4.5 × 2.5 inch end. After one hour the specimen is stood on end in a tank of flowing cold water so that the hotter portion of the brick (5 inches) is immersed. When pieces become loosened and fall off, the sample is laid on a 4.5 × 9.0 inch asbestos board, subdivided into 100 equal squares, and the approximate percentage of loss estimated."

Later it was found that a certain type of checker brick failed after about three immersions in water and that it was necessary to use the air blast in comparing[1] fire-brick of this type.

Part II.—Comparison of Laboratory Tests and Behavior in Service

The previously described test was used in this laboratory for nearly two years, and in every case gave results which were in harmony with the results of experience. During this period of time, however, it received a rather narrow application, for only samples which were made at the same plant were compared at any one time.

[1] A paper on this subject will appear in the near future.

FIGURE ONE

BEHAVIOR OF FOUR BRANDS IN AIR-COOLING SPALLING TEST

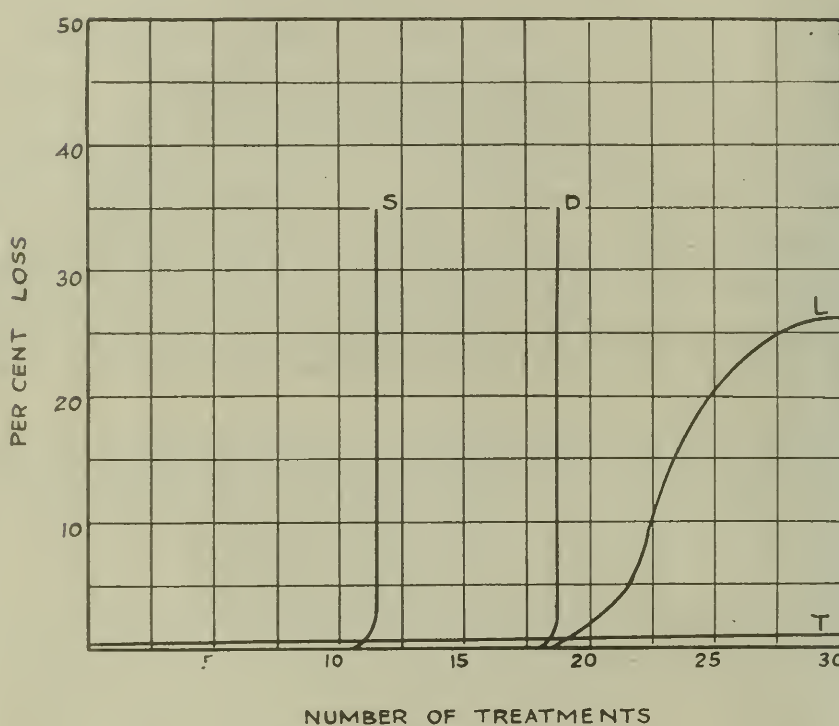


FIGURE TWO

BEHAVIOR OF FOUR BRANDS IN WATER-COOLED SPALLING TEST

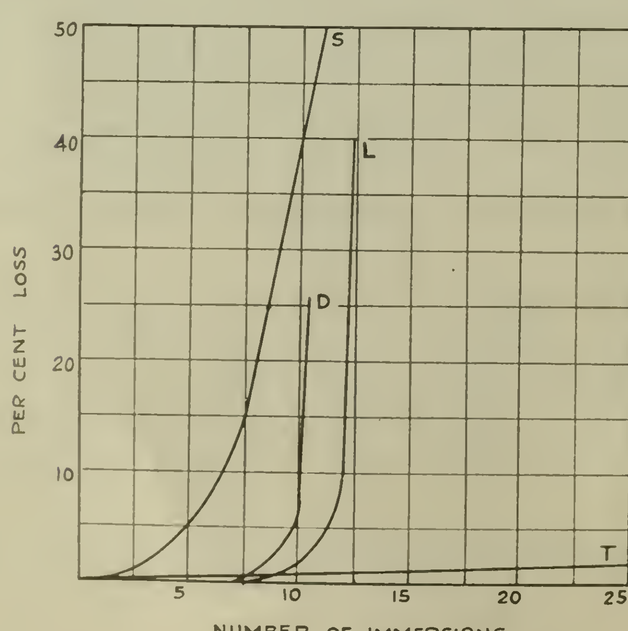


TABLE 2—SPALLING LOSSES OF DIFFERENT FIRE-BRICK WHEN COOLED BY AIR AND WATER

Number of times cooled	Per cent loss							
	T		S		L		D	
	Air	Water	Air	Water	Air	Water	Air	Water
1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1
2	.1	.1	.1	.0	.1	.1	.1	.1
3	.1	.1	.1	.0	.1	.1	.1	.1
4	.1	.1	.1	.0	.1	.1	.1	.1
5	.1	.1	.1	4.4	.1	.1	.1	.1
6	.1	.2	.1	.4	.1	.2	.1	.3
7	.1	.2	.1	9.6	.1	.2	.1	.3
8	.1	.2	.1	.6	.1	.2	.1	.3
9	.1	.2	.1	.6	.1	.9	.1	.3
10	.1	.3	.1	.6	.1	.9	.1	19.5
11	.2	.3	.1	.8	.1	.9	.1	..
12	.2	.3	.1	50+	.1	.9	.1	..
13	.2	.6	.1	..	.1	8.2	.2	..
14	.2	.6	34.0	..	.1	40.0	.2	..
15	.2	.6	..	..	.1	..	.2	..
16	.2	.6	..	..	.1	..	0.2	..
17	.2	.7	..	..	.1	..	.2	..
18	.2	1.0	..	..	.1	..	34.0	..
19	.2	.0	..	..	.1	..	..	..
20	.2	.0	..	..	.1	..	..	..
21	.2	.2	..	..	.1	..	..	..
22	.2	.2	..	..	.1	..	..	..
23	.3	.2	..	..	.1	..	..	..
24	.3	.2	..	..	.2	..	..	..
25	.3	.2	..	..	16.5	..	..	..
26	.3	.7	..	..	.5	..	..	..
27	.3	.7	..	..	.5	..	..	..
28	.3	.7	..	..	.5	..	..	..
29	.3	.8	..	..	.5	..	..	..
30	.3	.8	..	..	.5	..	..	..
31	.3	.8	..	..	23.3	..	..	..
32	.3	.8	..	..	.3	..	..	..
33	.3	.8	..	..	.3	..	..	..
34	.3	.8	..	..	.3	..	..	..
35	.3	.8	..	..	.3	..	..	..
36	.3	2.2	..	..	.3	..	..	..
37	..	.2	..	..	..	..	..	..
38	..	.2	..	..	..	..	..	..
39	..	.2	..	..	..	..	..	..
40	..	.8	..	..	..	..	..	..

FIGURE THREE
RELATIVE RESISTANCE TO SPALLING OF SEVERAL FIREBRICKS MADE AT THE SAME PLANT BUT BY DIFFERENT PROCESSES

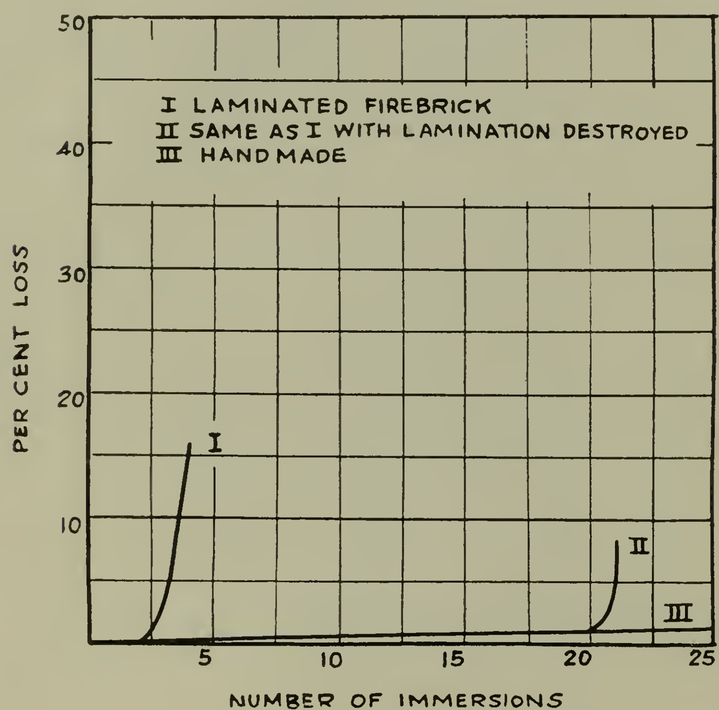
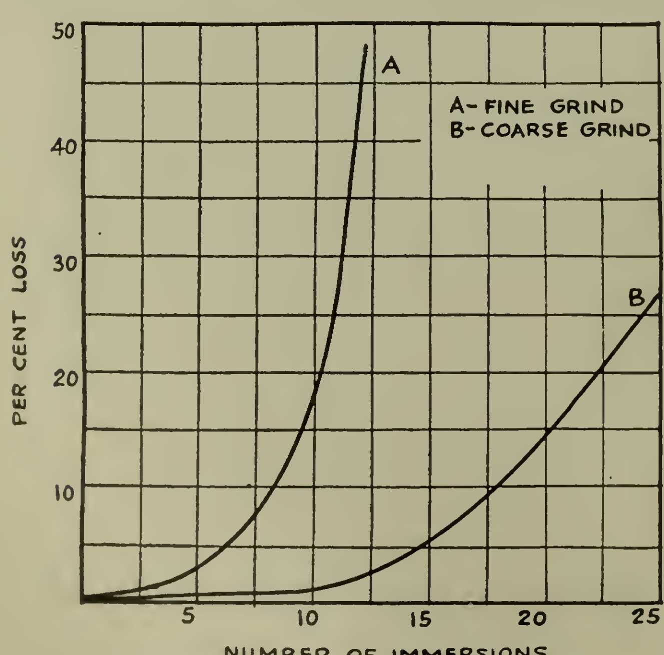


FIGURE FOUR
RELATIVE RESISTANCE TO SPALLING OF COARSE AND FINE GRAINED FIREBRICK OF SIMILAR COMPOSITION



In one instance three processes of manufacture were applied to a certain batch of clays. The resulting product was therefore of practically the same grind and burn, but differed considerably in structure. The results of the tests are given in figure 3, and show the decided structural differences of the different products.

In a second case the clays were ground to different sizes, but the samples were otherwise identical. The spalling test results secured from these specimens are given in figure 4. The advantage possessed by the coarser ground mixture, with respect to resistance to spalling, is evident.

A third citation refers to fire-brick which were made as nearly alike as possible except for hard and soft burning. The comparisons are shown by figure 4 and bring out the superiority of light burned products, from this standpoint, very strikingly.

The results shown in figures 3, 4, and 5 were considered favorable, because in each case they conform to what has been observed. In the following citation fire-brick of widely different characteristics were under consideration, and here the test results showed a decided lack of agreement with what is known to obtain in service. Fire-brick A is usually considered as a "non-spalling" roof brick; C spalls were A does not; B assumes an intermediate position. Other characteristics of these three brands are given in table 3.

TABLE 3—GENERAL CHARACTERISTICS OF FIRE-BRICKS A, B AND C

Ultimate Chemical Analysis	A	B	C
Per cent of silica	81.02	55.04	52.95
Per cent of alumina	16.58	39.91	42.95
Per cent of ferric oxide	1.46	3.65	2.32
Per cent of lime	0.40	0.48	0.10
Per cent of magnesia	.16	.28	.31
Per cent of soda	.32	.40	.67
Per cent of potash	.38	.39	.66
Total	100.32	100.15	100.20
Fusion point in cones	29	32–33	33
Compression in 1350° C load test	1.2%	4.8%	5.2%
Porosity of "run of kiln" brick	30.45	21.09	21.00
Porosity after reheating to 1400° C.	32.08	18.43	17.70
Porosity change during reheating	+1.63	− 2.66	− 2.30
Linear change after reheating five hours at 1400° C.	0.00	0.15% Exp.	0.61% Exp.

FIGURE FIVE

RELATIVE RESISTANCE TO SPALLING OF HARD AND SOFT BURNED BRICK

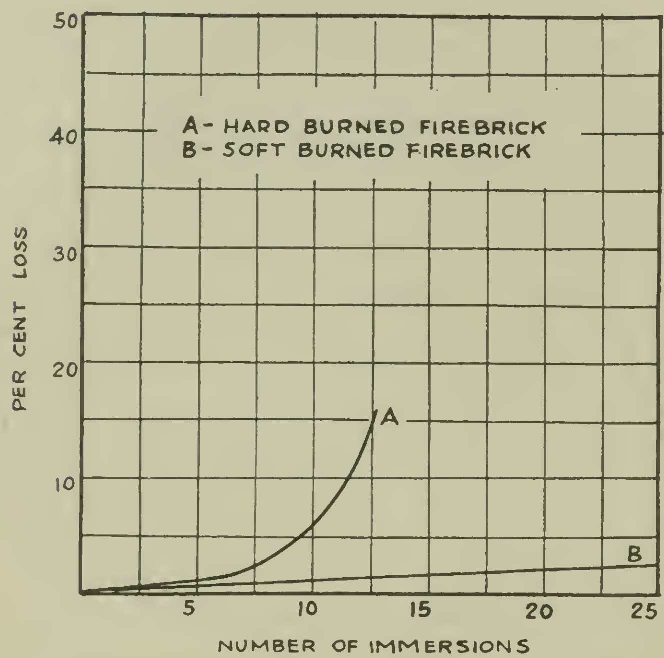
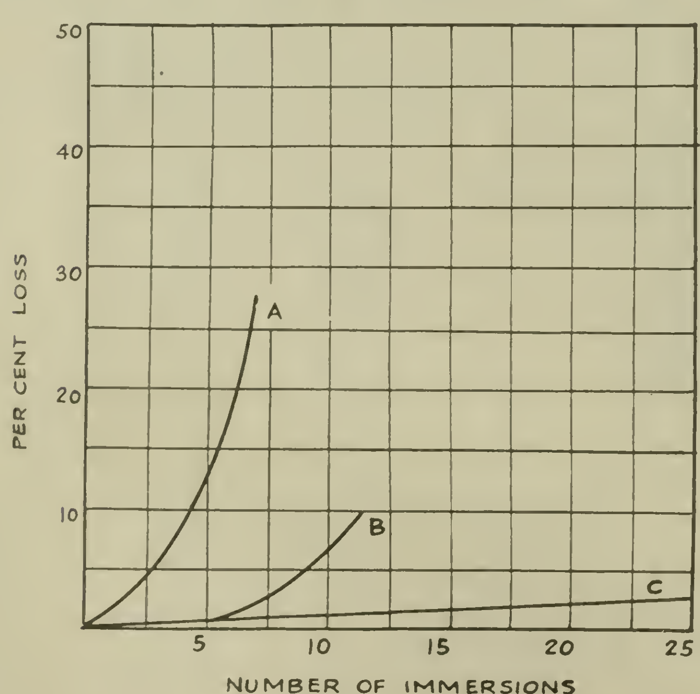


FIGURE SIX

SPALLING TESTS ON "RUN OF KILN" BRICKS "A," "B," AND "C."



The results of the spalling tests made upon these three brands are given in table 4 and are shown in figure 6.

TABLE 4—SPALLING LOSSES OF RUN OF KILN FIRE-BRICK WHEN DIPPED IN WATER

Number of dips	Per cent loss A	B	C
2	0.0	0.0	0.0
4	8.0	.0	.0
6	28.0	.7	.0
8	..	2.3	.0
10	..	4.7	.2
12	..	10.7	.5

In view of the facts developing by the preceding examples, the conclusion was drawn that the usual spalling test gives accurate information when the specimens are made from the same fire-clays, but when fire-clays from different districts are compared the results are not in accordance with their behavior in service.

Part III.—Further Development of the Spalling Test

There are two distinct types of fire-clay which, when used in the manufacture of fire-brick, give a product particularly resistant to spalling. The temperature porosity curves for two fire-clays of this nature are given in figure 7, and show that these clays are characterized by a constancy in porosity for a wide range of temperature.

Since clays of this kind undergo only a slight change in porosity when heated, they are considered as being very resistant to vitrification, for decrease in porosity is the best criterion of vitrification.[1]

It is also known that when fire-brick spall in service the pieces are usually dense or vitrified. Consequently, the possibility of a relation between vitrification and spalling was suggested. In order to develop this relation, specimens of fire-brick C were prepared by heating for five hours at 1200°, 1300°, 1400°, and 1450° C. This series therefore represented various stages of vitrification, depending upon the highest temperature to which the different samples had been heated.

[1] Brown and Murray, *Trans. Am. Ceram. Soc.*, 15, 173 (1913); Edward Orton, Jr., *Ibid.*, 16, 497 (1914).

FIGURE SEVEN

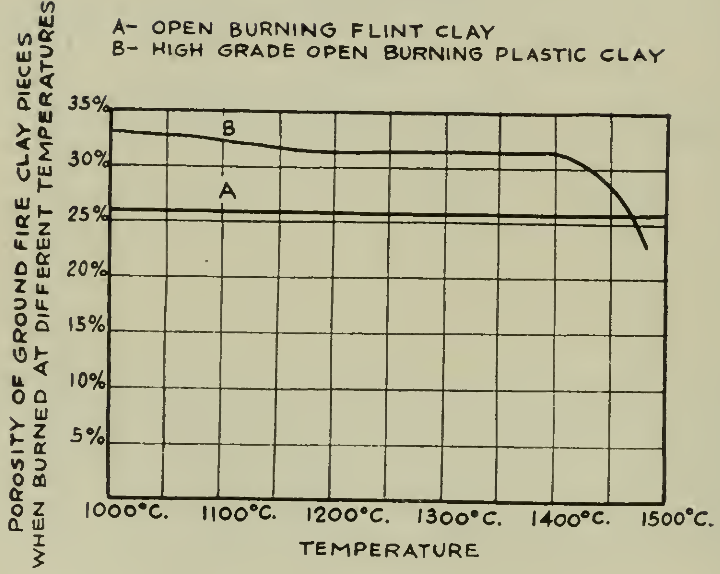
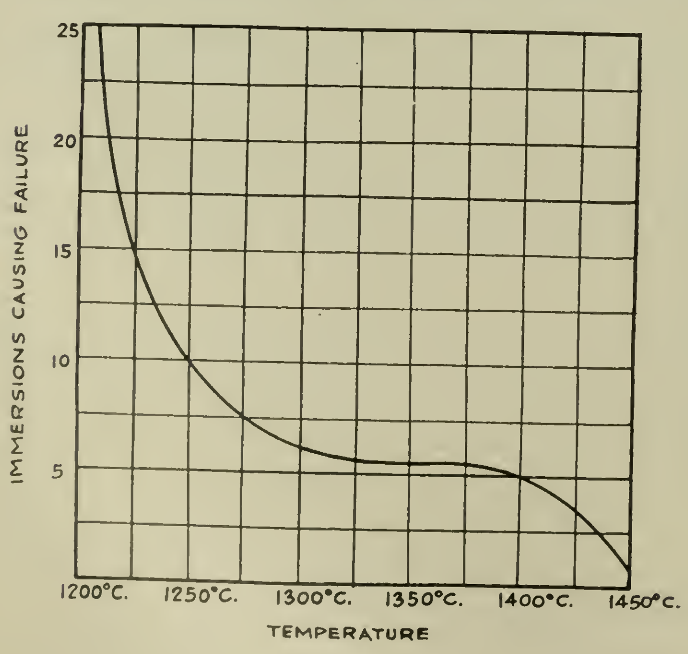


FIGURE EIGHT

RELATION BETWEEN SPALLING TENDENCY AND TEMPERATURE



The reheated samples were then subjected to the usual spalling test, with water as the cooling medium. When each specimen lost over 33 per cent the number of immersions necessary to produce this failure was recorded as its spalling value. These data were collected and plotted in figure 8, which shows very clearly that resistance to temperature change is a function of vitrification. It is a well-known fact that hard burned (or more completely vitrified) products have a higher coefficient of expansion than those which are soft burned. It has been demonstrated that the harder burned products are also less resistant to spalling. Consequently, it may be that the spalling of fire-clay brick is also associated with thermal expansion, as is the case with silica brick. In the case of fire-brick, however, the thermal expansion will vary with the hardness of burn or completeness of vitrification, and so resistance to temperature change should be considered a function of vitrification.

Vitrification *per se*, however, is not a constant factor, and both the rate and magnitude of the porosity change must be considered. Again, in some cases it may be the result of a predominatingly chemical action, while in others the action is largely physical,[1] and it is probable that no two clays vitrify at the same rate or in the same manner.[2] Therefore, it is reasonable to expect a change in the relative vitrification of almost any two fire-bricks when heated from 1100°C. to 1400°C. With this thought in mind several samples of A, B and C were heated for five hours at 1400°C. The porosity of C decreased 2.6 per cent, that of B decreased 2.2 per cent, and that of A remained practically constant. C became very dense during reheating, B underwent considerable change, but A showed no visible signs of vitrification.

These reheated specimens were then tested for spalling; one-half of them were air-cooled and the other half were water-cooled. The spalling test results obtained in this manner are given in tables 5 and 6 and in figures 9 and 10.

[1] Brown and Murray, *Trans. Am. Ceram. Soc.*, 15, 193 (1913).

[2] See curves. Bleininger and Loomis, *Ibid.*, 19, 601 (1917).

FIGURE NINE
SPALLING TESTS ON BRICKS "A," "B," AND "C" AFTER REHEATING 5 HOURS AT 1400°C. AND DIPPING

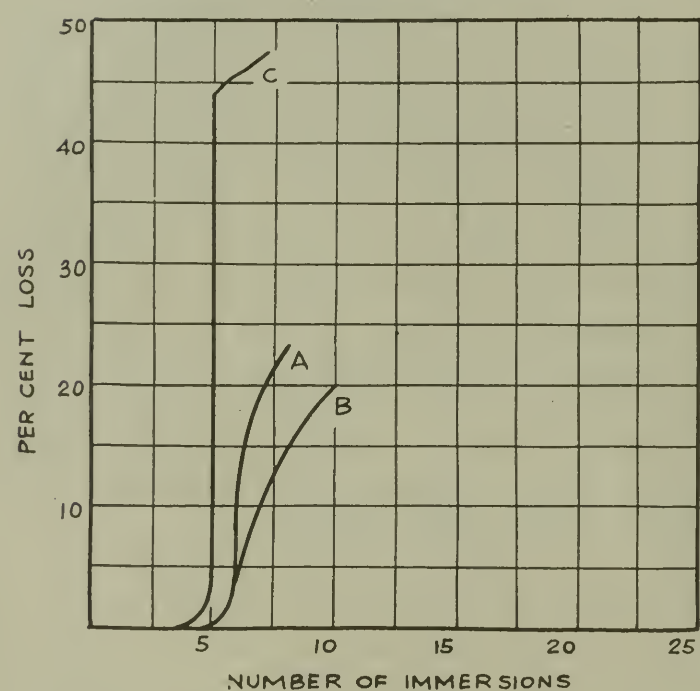


FIGURE TEN
SPALLING TESTS ON FIREBRICK "A," "B," AND "C" AFTER REHEATING FIVE HOURS AT 1400°C. AND SUBJECTING TO THE AIR-BLAST

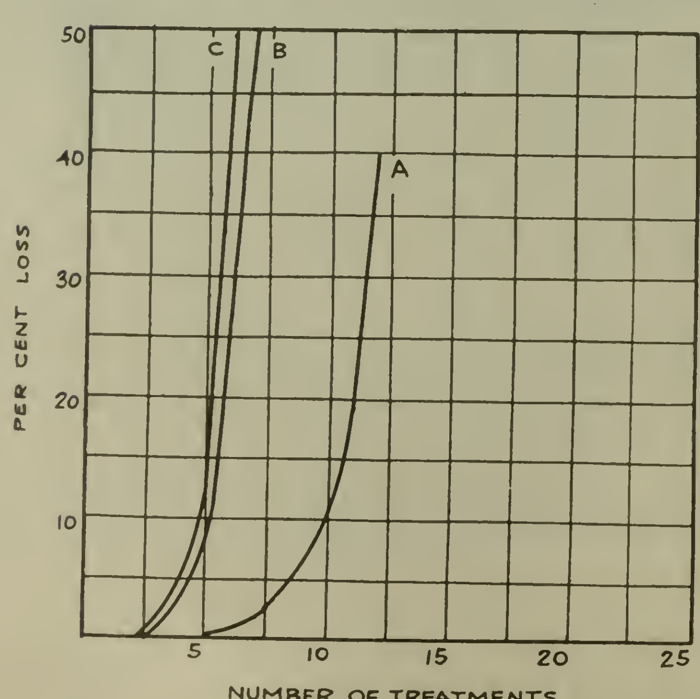


TABLE 5—AVERAGE PER CENT SPALLING LOSSES OF REHEATED SPECIMENS OF A, B AND C, WHEN COOLED IN WATER

Number of immersion	A	B	C
2	0.0	0.0	0.0
4	.0	.3	.0
6	.3	5.3	44.5
8	23.6	7.0	..
10	..	20.3	..

TABLE 6—AVERAGE PER CENT SPALLING LOSSES OF REHEATED SPECIMENS OF A, B AND C WHEN COOLED IN AIR

Number of treatments	A	B	C
2	0.0	0.0	0.0
4	.0	3.2	6.0
6	.0	19.8	50.0±
8	3.0	Broke after 7	..
10	5.0	..	..
12	39.8	..	..

When the various spalling test results are compared it is obvious that those secured from reheated fire-brick are in close agreement with service data. The position of C is changed entirely and A is given a more correct rating. For some unknown reason B did not give the expected results when reheated and water-spalled; when reheated and air-spalled it assumed the expected position. However, this slight discrepancy is overshadowed by the behaviors of A and C.

It should be noted that A, which is made from open burning fire-clay, underwent but very little change in resistance to spalling when reheated. C, which became very dense in reheating, suffered a radical decrease in resistance to spalling. Another point of interest concerns the fact that the air-cooling method, when applied to reheated fire-brick, gives sufficiently rapid results to justify its adoption.

In summarizing Part III it may be said that a relation has been shown between porosity, vitrification and spalling, for as vitrification increases, resistance to spalling decreases. Since vitrification is associated with porosity decrease it is believed that the following statement is justified:

"Fire-clays which undergo a slight change in porosity when heated over a wide range of temperature have a very slight

tendency to vitrify and are therefore particularly adapted to the manufacture of non-spalling fire-brick."

In view of the preceding results it is also evident that a broader interpretation should be given to spalling and the following statement may possibly meet this requirement:

When portions of fire-brick become loosened in service under the influence of fluctuations in temperature they are said to spall; density due to vitrification, improper brick structure, and unequally distributed stresses facilitate this action.

Part IV.—Application of Porosity-Spalling Theory

Within the past year certain hand-made special shapes, made of two clays used in equal proportions, were found to spall badly in service. When specimens were water spalled, however, they lost less than 3 per cent after twenty immersions. This test proved that the structure of the shapes was satisfactory, and suggested that the clays were at fault. Therefore porosity-temperature determinations were made for clays X and Y and these are given in figure 11. When these curves were examined it was obvious that the dense burning clay Y was more likely to be the cause of spalling than the open burning clay X. The composition of the batch was therefore changed so as to include only 20 per cent of Y, whereas the original batch contained 50 per cent of each clay. The theoretical porosity curve of the original batch is shown as Z and ZZ is the corresponding curve for the revised batch. The manufactures of these shapes have stated that spalling ceased when the composition of the batch was changed as above suggested. Thus, this case substantiated the porosity-spalling theory, and proved that spalling is not always due to improper fire-brick structure but is largely controlled by the thermal properties of the raw clays.

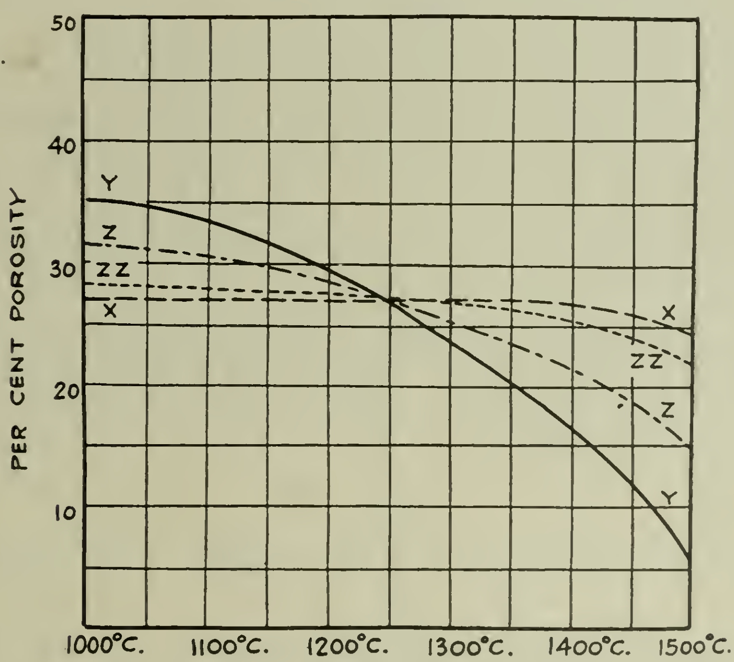
Undoubtedly this same procedure can be applied to the development of bung brick, glass pot mixes, and any other products that may spall.

Part V.—Application of Results to Testing

In Part II it was conclusively proved that the usual spalling tests give reliable information when applied to fire-brick made from the same clays. It was also shown that tests of this nature

fail when applied to fire-brick coming from different localities. This condition is undoubtedly due to the fact that fire-brick structure is overemphasized by the usual spalling test, while the characteristics of the raw clays are not revealed. The results given in Part IV are ample proof for this statement. Consequently, the development of a satisfactory spalling test is a relatively simple matter for any one manufacturer, but when a consumer buys his product from different sources the problem is more intricate.

FIGURE ELEVEN
POROSITY TEMPERATURE CURVE FOR CLAYS USED IN SPECIAL SHAPES



However, it is believed that the present investigation has revealed certain factors which can not be neglected in the development of a spalling test. It is essential that the fire-brick be given a severe heat treatment before they are air- or water-spalled. The severity of this treatment should depend upon the service in which the various samples are to be placed.

The objection has been raised that roof brick are heated on one surface only, while in the revised test they are heated throughout. This objection is not considered serious, however, because

of the fact that roof brick which will not vitrify in service will not vitrify in reheating, whereas fire-brick which tend to vitrify will do so both in service and in reheating.

Naturally, a dense burning fire-brick will spall more quickly either in service or in testing, if this characteristic is revealed; with an open burning fire-brick spalling in service is less noticeable and it has been shown that the resistance of specimens of this type to the spalling test is not decreased by reheating (see results secured with A). In other words, the practice of reheating is justified, or condemned, by the presence of, or lack of, a relation between vitrification and spalling. It is believed that this relation has already been establised.

A second objection to reheating the spalling test samples lies in the fact that many roof brick are purposely burned "soft" in order to secure the maximum resistance to spalling from a given set of clays. Reheating fire-brick of this type would undo a part of the work of the manufacturer, although treating different specimens in exactly the same manner might still leave them in the same relative order.

So far as can be determined at present there is no possible objection to reheating checker brick (at a temperature equivalent to the working temperature) before subjecting them to the air or water-spalling test.

It is believed that the preceding results warrant the following conclusions.

1. Air-cooling and water-cooling spalling tests give similar results.

2. These results lead to accurate conclusions where the same fire-clays are involved, but misrepresent the facts when different clays are concerned.

3. These discrepancies may be overcome by reheating the test specimen before subjecting it to the spalling test.

4. The necessity for reheating arises from the great differences in the vitrification behavior of different fire-clays.

5. Vitrification is closely associated with spalling.

Refractories Manufacturers Association Multiple Fellowship No 4
Mellon Institute of Industrial Research
Pittsburgh, Pa.

February 25, 1920

A READING LIST ON VITREOUS ENAMELING ON IRON AND STEEL[1]

By Clarence Jay West

The literature of the ceramic industry is very well covered up to the year 1906 by the Bibliography of Clays and the Ceramic Arts compiled by John C. Branner. The following reading list, therefore, begins with the year 1907. The articles listed deal more with the chemical principles involved than with mechanical methods. References are given to the abstracts printed in Chemical Abstracts or in the Journal of the Society of Chemical Industry. These abstracts are reproduced in part below, though where the abstract is long, or where the title indicates the scope of the article, abstracts are usually omitted. Reference to abstracts will enable the investigator to eliminate many articles as being unsuitable for his particular purpose. United States patents on enameling are omitted, as they have been in This Journal, vol. 3 page 893 to 900. Directions for ordering foreign patents may be found in Chemical Abstracts, vol. 13, no. 6 (March 20, 1919).

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[1] Received Oct. 5, 1920.

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Grünwald, J. The technology of iron enameling and tinning. 1912. London: C. Griffin and Co. 138 pages.

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Chem. Fabrik Güstrow, Hillringshaus, and Heilmann. Manufacture of a white translucent enamel. German Patent 207,001. Aug. 6, 1907. *C. A.*, **3**, 2044. A small amount of cobalt oxide is added to the enamel material containing titanic acid with the view of covering the yellowish tint of the titanic flux.

Chem. Fabrik Güstrow. White clouded enamels. English Patent 12,583, May 30, 1907. *C. A.*, **3**, 587; *J. Soc. Chem. Ind.*, **27**, 810. Artificially produced titanates of alkaline earth or earth metals are used.

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Schuler, A. J. Roughening of enamels. *La Ceramique*, **16**, 239–40; *C. A.*, **8**, 224. Quartz, feldspar or kaolin is mixed with a cover compound of earths or silicates and salts before application to the object.

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Weiss, L. Opaquing agents for enamels. French Patent 459,999, June 23, 1913. English Patent 14,632, June 24, 1913. *C. A.*, **8**, 2932; **9**, 136; *J. Soc. Chem. Ind.*, **32**, 1157. Fluorides or double fluorides of tin, antimony, titanium, zirconium are used. The effect is increased by the presence of hydroxides of the alkalies and alkaline earths or of silicon compounds.

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Landrum, Robert D., and Frost, Leon J. Titanium enamels. *J. Am. Ceram. Soc.*, **3**, 316–21 (1920); *C. A.*, **14**, 2688. The good qualities resulting from the use of titanium seem to more than offset the bad ones and it seems possible to overcome some of the difficulties and develop enamels of very substantial practical value.

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INFORMATION DEPARTMENT
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NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

NOTE ON SILICA BRICK*

D. W. Ross

Considerable work has been done on the thermal expansion of the various forms of silica, and upon the phenomena attending the transformation of one form into another through the influence of heat. It is possible, however, that not many careful studies have been made of the combined effects of the above, as they occur in the crowns of industrial furnaces. It has been the writer's good fortune to have an opportunity to become familiar with such a case, and we believe it is of sufficient interest to silica brick users to bear repeating.

The plant in question consists of several tank furnaces used in the manufacture of bottle glass. These furnaces are equipped with regenerators in which the fires are reversed every 20 minutes. Each tank covers approximately 20 by 60 feet of floor space. The supports for the silica brick crowns of the tanks are independent of the side walls, so that the side walls may be removed without changing crowns.

This plant has been in operation for a number of years, and during this time rough data have been kept concerning the silica brick crowns. To this end a horizontal straight edge has been placed over the center of each furnace and parallel to the axis of the crowns, but independent of the furnace. These serve as a means of measuring the rise of the crowns during heating. The expansion across any crown is measured either by the number of threads let out at the tie rods, or by direct measurement between opposite buckstays.

From observations during the extended period that the plant has operated, some general conclusions have been arrived at. These may be briefly summarized as follows:

1. That great care is necessary in heating up a new crown, due both to large expansion of the whole crown and to unequal

* Received Feb. 27, 1920.

expansion from place to place; some spots expanding considerably more than others.

2. That after 18 months (or more) service a crown can usually be cooled without disruption, providing the temperature is kept from dropping too suddenly after the fires are turned off.

3. That a crown so cooled can be reheated and during reheating gives less trouble than it did when it was first heated up. For on reheating, crowns, roughly speaking, only expand one-half (0.5) as much as they did during the first heating, and local non-uniformity is practically absent. Hence, reheating can be conducted considerably more rapidly than the original heating, without causing trouble.

4. That when a crown has been cooled after being in use 18 months a large percentage of the brick are broken in two, or at least contain a zone of weakness approximately midway between the inside and outside of the crown.

Microscopic examination of portions of the interior of a used crown (approximately 18 months service) indicated that it was practically all tridymite but contained a slight amount of calcium monosilicate crystals scattered through it and a slight amount of glass. It is possible that there was a trace of cristobalite present, but no quartz, whatever was reported. The inner tridymite portions were practically pure white, while the zone immediately back of this was of a darker reddish tan color than is found in most unused silica brick. The outside of the crowns never get hot enough to allow much changing of the silica from one form to another, and silica brick received from the manufacturer are largely cristobalite and quartz.[1]

From the above it seems probable that in reheating used crowns, the lesser expansion and the ability to withstand more rapid heating than was permissible with the crown when new, is on account of the silica of the inner part of the crown being almost wholly in the form of tricymite. The local non-uniformities of expansion in new crowns are in all probability caused by non-uniformities of burn of the brick when manufactured.

Cosmo Johns[2] has said that the breaking of silica brick ap-

[1] U. S. Bureau of Standards, *Tech. Paper* 116, (1919).

[2] Cosmo Johns, *Journ. Soc. Glass Tech.*, 1, 137 (1917).

proximately midway between the interior and exterior of used crowns is in a narrow field in which the inversions vary back and forth with fluctuations of the temperature of a crown while the furnace is in heat.

It appears possible that the fact that one end of such brick is largely tridymite while the other end is mostly quartz and cristobalite may also have a very important bearing upon this cracking of the brick at or near the middle.

The effect of migration of iron, and so forth, from one part of a silica brick to another, while in use, as noted by Rengade[1] may also exert an influence.

FINDLAY CLAY POT CO.
WASHINGTON, PA.

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

[1] E. Rengade, Acad. of Sci., Paris, May, 1918. Reference obtained from *J. Ind. Eng. Chem.*, **12**, 1148 (a paper by W. F. Rochow).

CORRECTION

A High-Temperature Transverse-Strength Test as a Method of Testing Sagger Mixtures, S. C. Linbarger and C. F. Geiger, THIS JOURNAL, Vol. **3**, 548, line 23 for "at 1200°" read "at 1300°."

CHARLES F. GEIGER.

CERAMIC ABSTRACTS[1]

General

A rapid method for the relative porosity determination of ceramic bodies. Léon Bertrand, *Céramique*, **23**, 77 (1920); *Sprechsaal*, **53**, 443–444 (1920). —The customary method for determining the porosity is by the formula $\frac{P_1 - P_0}{P_1 - P_2}$ in which P_0 = dry weight, P_1 = wet weight and P_2 = suspended weight. In using this method it is necessary to determine 3 weights whereas in the new method it is only necessary to know 2 weights. In making the suspended weight the test piece is immersed under a liquid by means of a wire. A small additional pan is attached to this wire to determine the difference between P_0 and P_1. The test piece is attached to the wire and the scale is balanced by putting weights on the opposite large scale pan. The test piece is then immersed in the liquid and after all absorption has ceased the scale is again balanced by putting weights on the small scale pan. This weight equals $P_0 - P_1$. The saturated test piece is now removed from liquid, wiped and again attached to wire and the weights are removed from the small scale pan. The balance is again balanced by putting additional weights on the large scale pan. These addition weights equal $P_1 - P_0$. Let $p' = P_0 - P_2$ and $p'' = P_1 - P_0$. The porosity is then $\frac{p''}{p' + p''}$. For this work it is desirable to use carbon tetrachloride because of its low surface tension. It was found that $^1/_4$ hr. was usually sufficient to completely saturate the test pieces and in no case was more than 2 hrs. necessary whereas with water it is often necessary to soak 24 hrs.

H. G. Schurecht.

The shrinkage, porosity and other properties of a china clay after being fired at various temperatures. Miss E. M. Firth, F. W. Hodkin, W. E. S. Turner. *Jour. Soc. Glass. Tech.*, **4**, 264–7.—The material used was a typical commercial English china clay, the calculated analysis of which indicated that it consisted of 87 per cent kaolinite, 11 per cent orthoclase with small amounts of other minerals. The clay was made up with $49^1/_2$ per cent water

[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the editor of Chemical Abstracts by coöperative agreement.

to a very smooth and fairly plastic mass. The properties at various temperatures were as follows:

Firing temperature °C	Shrinkage	Porosity	Apparent density	True density
110	3.30	..	..	..
200	.32	..	..	..
350	.38	..	..	..
500	.61	..	..	..
600	.92	51.5	1.20	2.46
750	4.14	52.5	.19	.53
900	.48	56.2	.14	.56
1000	5.72	52.0	.25	.62
1100	10.94	45.6	.41	.60
1200	14.71	31.7	.77	.60
1300	18.72	14.5	2.19	.56
1400	21.15	8.3	.36	.56
1500	22.08	2.4	.44	.51

E. RODGERS

The human factor in industry. G. H. MILES. *Jour. Soc. Glass Tech.*, 4, 267–281.—A general discussion of the subject in which special emphasis is laid on the employment of modern psychological tests in vocational training and guidance. This was followed by a description of the National Institute of Psychology and Physiology which is now being established in England for the purpose of research in the field of vocational guidance and industrial psychology and applying the results to industry. E. RODGERS.

Refractories

Strength of refractories at different temps. V. BODIN. *Ceramique*, 23, 177–184 (1920).—The strength of refractories at different temps. were measured on $^3/_8''$ cubes heated in a gas furnace. It was found that for fire-clay, bauxite, corundum, carborundum, silica and zirconia refractories the crushing strength decreases with an increase in temp. up to about 800° C. Above this temp. the strength increases rapidly with an increase in temp. until about 1000° C. is reached, after which the strength again decreases with an increase in temp. With magnesite and chrome refractories the strength decreases with an increase in furnace temp. showing no increase in strength at 1000° C. For ex. a bauxite having the following chem. analysis was fired at 1300° C. and 1500° C. after which it was tested at different temps.: SiO_2 13.3, TiO_2 3.35, Al_2O_3 61.05, Fe_2O_3 4.75, CaO 0.95, MgO 0.10, SO_3 trace and loss on ignit. 16.45:

Temp. °C	Kilograms per cm². Bauxite fired at 1300° C	Bauxite fired at 1500° C
20	395	660
600	300	380
700	285	350
800	270 minimum	360 minimum
900	350	570
1000	715 maximum	685 maximum
1100	330	500
1200	120	260
1300	55	95
1400	30	40
1500	15	15

Tests made on other refractories gave the following results:

Type	Compress. strength kgs. cm². 20° C	800° C	1000° C	1300° C	1500° C
Fire-clay A	195	125	105	740	40
Fire-clay C L	920	555	575	360	65
Fire-clay P	1110	485	755	115	20
Corundum	790	530	615	310	30
Carborundum	415	425	585	150	70
Silica brick S	180	90	80	60	40
Silica brick V	240	125	185	160	100
Fused quartz	2550	1040	780	1670	100
Zircon	395	275	345	90	10
Magnesite	450	205	190	155	30
Chrome	450	450	425	215	75

H. G. SCHURECHT.

Electric furnace refractories. A. F. GREAVES-WALKER. *Chem. Met. Eng.*, **23**, 933–36.—The basic refractories available for making electric furnace linings are magnesite, dolomite, zirkite, alundum, carborundum, bauxite. The neutral are chromite, zircon, carbon, and fire-clay. Silica is the only acid refractory given. The properties of these various refractories are discussed briefly. The refractories recommended for melting various metals are: steel ingots and castings, magnesite for high grade steels, silica for ordinary steels or when selected pure scrap is used; alloy steels, magnesite exclusively; ferromanganese, magnesite or carbon; ferrochrome, magnesite or chrome; ferrosilicon, silica; cast iron, fire-clay for low temperature melting, silica for high temperature melting, magnesite on irons of special low sulphur and phosphorous requirements; copper, magnesite on bronze scrap or pig containing lead, silica or magnesite on refined pig and pure scrap; bearing metal, magnesite with as low silica as possible; monel metal, magnesite preferable but silica can be used; bronze, silica preferable but magnesite can be used where zinc is not too high; lead, magnesite exclusively; silver, silica; aluminum

and its alloys, magnesite exclusively. Many of the failures of refractories in electric furnace linings are due to poor construction and especially failure to provide sufficiently numerous expansion joints. In many cases refractories are ruined by improper handling and exposure to weather before they are placed in service. A. J. LAMBERT.

Refractories for electric furnaces. ANON. *Mineral Foote-Notes*, Sept.-Oct., 3–7 (1920).—Electric furnaces may be roughly divided into two classes, namely, those for ferrous and those for non-ferrous metals. For ferrous melting the arc furnace in its various modifications is in general use. In non-ferrous industries, arc, radiation and induction furnaces are in use. The non-ferrous furnaces are low temp. units when compared with those used in the ferrous industries since the aim in non-ferrous furnaces is to work at minimum temps. so as to avoid volatilization losses. Furthermore, non-ferrous furnaces are intended for melting only whereas ferrous furnaces are intended for refining as well as melting which means a more vigorous slag action on the refractories. Some special requirements for electric furnace refractories are the following: (1) The melting point should be between 1700° to 1750° C. (2) They should be very resist. to sudden temp. changes since a heat is often completed 2 hrs. after starting from the cold. (3) The refractories should not change in volume at electric furnace temps. Brick fired in fuel-fired kilns often shrink considerable when fired at the higher electric furnaces temps. (4) The brick should be very resist. to corrosion since oxidizing and reducing slags are often present and these together with the high temps. cause vigorous corrosion of the refractories. (5) Where a circulating metal bath is used as in induction furnaces the refractories should be very resist. to abrasion. Different parts of the furnaces must meet the following requirements: (*a*) The outer walls should be a good heat insulator and moderately refractory. (*b*) The hearth should have a high melting point, be inert towards slags and be resist. to erosion. (*c*) The roof should be resist. to slags and fumes, should have no tendency to spall and have a high melting point. The present practice is to use a good grade of fire-brick for the outer wall, this sometimes being laid next to silocel, asbestos or a similar insulator. Magnesite brick are laid against the fire-brick for forming the inner side walls of the furnace and one or two coarses are laid over the bottom layer of fire-brick. The rammed in or built up hearth is then built in with dead-burned magnesite, dolomite or "syndolag." The roof is most frequently made of silica brick, although carborundum and electrically fused magnesite have also been used. The refractories now used in electric furnaces fail to meet the requirements. It is suggested that zirkite may be an excellent refractory for electric furnaces since it meets most of the above requirements. H. G. SCHURECHT.

Glass

Note on the density of soda-magnesia glasses. C. J. PEDDLE. *Jour Soc. Glass Tech.*, 4, 281–3.—The density of a series of glasses containing five molecules of SiO_2 were found to be as follows:

Molecules		
Na_2O	MgO	Density
1.75	0.25	2.453
.625	.375	.448
.50	.50	.444
.375	.625	.439
.25	.75	.433
.00	1.00	.421

From a study of these results and comparison with those obtained by Turner (see THIS JOUR., **3**, 927) the following conclusions were drawn: In glasses where the molecular SiO_2 and Na_2O content remains constant, increasing the molecular content of either MgO or CaO raises the density. Where the SiO_2, MgO or SiO_2, CaO content is the same in two glasses, the one with the higher molecular Na_2O content will have the higher density. The rate of increase of density per molecule of CaO added is much greater than the rate of increase per molecule of MgO added. The rate of increase of density diminishes in both the MgO and CaO glasses as the amount of magnesia or lime increases, and this diminution is most marked in the series containing the most Na_2O. In two like series of CaO and MgO glasses, the lime glasses have a higher density than the magnesia glasses. E. RODGERS.

Expansion of glass at high temperatures. W. B. PIETENPOT. *Chem. Met. Eng.*, **23**, 876–7.—Expansion of various glasses in strips 76 cm. long was measured from room temperature to 750° C. The rate of expansion of annealed glass is nearly linear up to temperatures of 450 to 550° C. depending upon the kind of glass. The rate of expansion then increases by four to six times, through a temperature range of 60 to 100° C. After the rapid increase in expansion the rate of expansion again becomes nearly linear, in general being slightly greater than at low temperatures. When the softening point is reached the rate of expansion gradually decreases and the length of the strip remains constant. At this point the glass loses its form. With unannealed glass the rate of expansion in general decreases from 50 to 150° before the rapid expansion takes place. This decreased rate may continue through a temperature range of 100 to 150°, depending upon the strain in the glass. In some instances the expansion through a range of 100° is practically zero. Upon cooling, the strip of glass is shorter by a definite amount which is proportional to the strain which has been relieved. A. J. LAMBERT.

The factory inspection of glassware. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **4**, 253–61.—According to the class of ware being made, tests from the following list should be applied: poor color; uniformity of weight; uniformity of capacity, test of size of neck by a standard gauge; uniformity of thickness; cracking test; determination of bursting pressure; accuracy of graduation; absence of seeds, blisters, and cords; examination in the polaris-

cope for state of annealing in the case of glass other than dark metal. The cracking test is applied by filling the bottle with water, heating it slowly to not less than 70°, and chilling it suddenly in water at 20°, afterwards repeating the test at 75° and 80° if the bottle has not previously been cracked. Good bottles should withstand sudden chilling from 75° to 20° without cracking. The cracking test is really a test both of the uniformity of thickness and of the state of annealing, and is the only method of obtaining evidence on the state of annealing when the bottle is too dense in color to permit of examination by the polariscope. E. RODGERS.

On certain surface effects in glass, probably produced by reheating in the glory hole. MORRIS W. TRAVERS. *Jour. Soc. Glass Tech.*, 4, 284–6.—In glasses that have been worked in glory holes, small bubbles appear immediately below the outer surface. It is suggested that this is due to the evolution of dissolved gases due to the fact that the surface of the glass is intensely heated by radiation from the burning coal or coke, the glass as a whole being opaque to radiation. A. J. LAMBERT.

Automatic feeding devices for glass-making machinery. HOMER BROOKE. *Jour. Soc. Glass Tech.*, 4, 296–8.—The utilization of a flowing stream of molten glass from the furnace and cutting from it predetermined quantities of glass at a definite rate (30 to 90 per minute), the portions of glass then being served to automatic machines to make ordinary articles of glassware, has been successfully carried on for a number of years in the United States and Canada under patents granted to the author in the United States, Canada, Great Britian, France, Belgium, and Germany. The patents have now expired and are therefore open to all. A. J. L.

Casting of pots for use in experimental work on optical glass. ALICE B. TAYLOR. *Jour. Soc. Glass Tech.*, 4, 251–3.—Reply to discussion. In pots cast under pressure the total shrinkage after firing to 1480° is less than that of the same slip cast in the usual manner with the same proportion of alkali. The drying shrinkage is very much less. Bubbles in the base of the pots occurred only when slip below a certain viscosity was used and where the time of filling was very rapid. The appearance of the bubbles and their position indicate an encircling and entrapping of air in the mold by the back wash of the slip after striking against the core of the mold. Since rapidity of rise is an asset in assuring even distribution of grog and clay, enough pressure was put on to send the slip up quickly but smoothly without splashing. It was then reduced somewhat. If a pressure of 15 to 25 lbs. per sq. in. is maintained for a considerable time there is a tendency for the pot to crack upon the core. E. RODGERS.

Some developments in the study of glass technology in the year 1919–1920. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, 4, 287–96.—This comprises the 4th annual report of the Delegacy for Glass Research. The year's work has been marked by steady development rather than by outstanding events.

Thirteen papers dealing with glass research have been published. In addition five others were read before the Society of Glass Technology and will be published later. One hundred and fifty-eight cases of inquiry from glass manufacturers have been dealt with. Sixty-eight of these involved more or less experimental work. Twenty-three students have been taking full time university courses. Local center courses have been carried on at Barnsley, Leeds, London, Mexboro and Sheffield. Ninety-four students were enrolled in these classes. Six lectures were given to an aveiage attendance of 200 persons at Stourbridge. Fifty-nine students, practically all disabled soldiers, were enrolled in the lamp working school. Fifty-two hundred pounds were expended and £4500 received for the Delegacy work leaving a deficit of £700. Among the contributors to the fund were five glass manufacturers associations. A. J. Lambert.

Device for measuring the internal diameter of glass tubing. Verney Stott. *Jour. Soc. Glass Tech.*, **4**, 261–3.—The instrument consists of a thin-walled brass tube in which a rod carrying a cone at its lower end is free to move. A brass ring is soldered into the bottom and attached to this are three springy brass wires placed on radii which make angles of 120° with each other. These wires are all of the same length, and at the upper end of each a phosphor bronze ball is fixed. As the cone is pushed down the tube it comes into contact with the three balls, and presses them outwards as it descends. The tube is cut in order to allow the phosphor bronze balls and the wires attached to them to move freely in and out. When the instrument is placed with its lower end inside a glass tube, the cone can be pushed in until each ball is in contact with the inside of the glass tube, but when this happens the cone can descend no further. The diameter is then read off on the scale engraved on the rod. A ferrule is made so as to be a spring fit on the outside of the tube. This facilitates the measurement of internal diameters at any desired distance from the end of the tube to be measured. The instrument is graduated and calibrated by the aid of standard ring gauges.

E. Rodgers.

PATENTS

Furnace for melting glass and other purposes. John Schofield Shaw. U. S. 1,359,756, Nov. 23, 1920. A furnace for melting glass and other materials in which a regenerator for the air is dispensed with. A bath for receiving the material to be melted is arranged in the interior of the furnace having a combustion chamber above it, two sets of longitudinal flues arranged on different levels below the bath and one air flue longitudinally arranged above the bath. One of the lower sets of flues is employed for the admission and heating of the cold air by the radiation of the heat from the bottom of the bath during its passage from the outside of the furnace to the combustion chamber, the other set is employed for conveying the waste gases and products of combustion from the rear end of the combustion chamber. The incoming air and the waste gases are arranged to travel in opposite directions. Two

vertical flues are provided at the rear of the furnace for respectively connecting the lower air inlet flues with the upper longitudinal flue, and with the rear of the furnace. Provision is made for a number of passages for connecting the upper longitudinal flue to the combustion chamber, and for a gas chamber connected by a number of passages to the combustion chamber for conveying the gas to the chamber for combustion purposes.

Glass-cutting frame. FRANK C. REMSBERG. U. S. 1,357,474, Nov. 2, 1920. A glass cutting frame comprised of oblong pieces arranged in a plane, additional pieces crossing the first mentioned pieces and secured thereto, the pieces forming a substantially quadrilateral, lattice-like frame, and stops foldably mounted on the frame adjacent an edge of the frame for abutment by a straight edge.

Device for severing glass. HARRY F. HITNER. U. S. 1,359,172, Nov. 16, 1920. In a glass cracking off device, a heating chamber, a reel in the chamber, a flexible cracking off member wound on the reel and adapted to be withdrawn from the chamber and means for heating the chamber.

Method of and apparatus for making sheet glass. THOMAS S. OWENS. U. S. 1,358,390, Nov. 9, 1920. The method consists in drawing a sheet of glass continuously upward through the air from a pool of molten glass, with the surface of the sheet free from contact with extraneous material until a glaze has formed thereon, bending the sheet over a roll having a surface which will not mar the glass, and maintaining a sliding contact between the surfaces by rotation of the roll. C. M. SAEGER, JR

Enamels

The use of zinc sulphide for white and luminous enamels. J. SCHAEFER. *Taschenbuch für Keramiker, Keram. Rundschau*, 29–35 (1919).—Owing to the high cost of SnO_2 as an opacifier for enamel, substitutes for this are important. The use of zinc sulphide (German patent 289,317) has attracted considerable attention because it is comparatively cheap. A series of experiments were run to determine if zinc sulphide or zinc oxide produced opacity in enamels. A very fusible enamel was used containing about 5 per cent cryolite and the enamel was fired at 800° C. In experiment (1) 5 per cent ZnS and 6 per cent clay were added to the mill. A opaque glaze was obtained with a yellowish tinge probably due to the Fe in the sulphide. In experiment (2) 4.1 ZnO and 6 per cent clay were added. This enamel did not cover well showing that ZnS and not ZnO is necessary to produce opacity Another series of experiments showed that ZnS is not destroyed in less fusible glazes unless certain metals which have a strong affinity for Zn are present The more refractory enamels containing ZnS however are not as glossy as the same containing SnO_2. A number of patents have been granted for making luminous enamels with luminous ZnS since the chem. compos. is not very different from that of pure ZnS. Luminous ZnS (*i. e.*, radio active ZnS) has

been used for some time with transparent varnish for various instruments. The disadvantage of using varnish as a binder is that the radioactivity of the paint has only a short life, being practically gone at the end of 3 yrs. whereas luminous enamels would probably last 10 yrs. It is necessary that 40–50 per cent luminous ZnS be added to an enamel to produce sufficient luminosity in the dark and for this purpose a very fusible enamel seems best suited. Enamels containing ZnS can not be used to make colored enamels since the coloring oxide would combine with the ZnS producing poor colors.

H. G. SCHURECHT.

Whiteware and Porcelain

Firing hard porcelain with wood gas. M. LARCHEVÊQUE. *Ceramique*, **23**, 73–7 (1920); *Keram. Rundschau*, **28**, 389–90, 401–2 (1920).—Owing to the fuel shortage in Europe experiments were run to determine if gas generated from wood could be used to fire hard porcelain. It was found that it was easy to reach the necessary temp. and that porcelain as well as other ceramic wares can be fired with wood gas. Wood gas has the advantage in that it contains no sulphur and ashes and hence most of the ware may be set in the open fire. The best woods for this purpose are oak, birch and beech.

H. G. SCHURECHT.

The physical properties of whiteware glazes. R. RIEKE. *Ber. der Tech. wiss. Abt. des Verb. keram. Gewerke*, **5**, 8–15 (1919).—In general it might be said that crazing of glazes is due to a difference in the coeff. of expansion of the glaze and body. Although a high elasticity and tensile strength may prevent crazing where the expansion of the body and glaze are different, such glazes are not very durable as they often craze after a long time. For hard-burned porcelains and porcelain glazes the expansion increases uniformily with an increase in temp. The coeff. of expansion of Berlin tech. porcelain at 700° is 35×10^{-7}, while porcelain glazes vary from 27×10^{-7} to 42×10^{-7}. It is possible, therefore, to pick glazes which have the same coeff. of expansion as porcelain. With stoneware it is impossible to get a glaze which expands and contracts the same as the body, since stoneware bodies always contain considerable free silica. Cristobalite shows a sudden change in vol. at 200°. Since even low melting glazes are no longer soft at 200°, the stoneware in contracting suddenly at this temp. on cooling causes cracks in the body or glaze. Furthermore, with glazes which harden above 500°, strains are produced owing to the conversion of α and β quartz at 575°. The coeff. of washed kaolin is about 40×10^{-7} to 80×10^{-7}. A stoneware containing 25 per cent flint and fired at cone 7 had a coeff. of expansion of 130×10^{-7} between 15° and 200°; 70×10^{-7} between 200° and 500°; 140×10^{-7} between 500° and 600° and 50×10^{-7} between 600° and 1000°. The coeff. of expansion of whiteware glazes varies between 57×10^{-7} and 96×10^{-7}. It is therefore impossible to fit a glaze to a stoneware body with such varying expansions. The modulus of elasticity of a glaze varies between 5700 and 6800 kg./sq. mm., which is a very small range. It may be said, therefore, that

the coeff. of expansion of glazes may be varied between comparatively wide limits by means of their chem. compn., but the modulus of elasticity can be varied but slightly by this method. The tensile strengths of most whiteware glazes probably lies between 5 and 8 kg./sq. mm., although some are as low as 3.5 kg./sq. mm. Of the above properties the coeff. of expansion is the most important. The tensile strength is more important than the modulus of elasticity. If two glazes have a modulus of elasticity of 5000 and 7000 kg./sq. mm., respectively, and a tensile strength of 5 kg./sq. mm., a rod of 10 cm. long would be expanded 0.10 mm. and 0.07 mm., resp., with a load of 5 kg./sq. mm. If the tensile strength is 8 kg./sq. mm. and the max. tension applied the expansion would be 0.17 mm. and 0.11 mm., resp., for the glazes with different moduli of elasticity. [*C. A.*]

Porcelain money. ANON. *Keram. Rundschau,* 28, 435–7 (1920).—Porcelain money is now being substituted for the more unsanitary paper money in Germany. To make this money a good bond clay together with a more refractory clay is used. The clays should be hand picked and free from pyrites. The grog is made of well sintered clay. The body should show no black spots or swelling when fired to 1400° C and should have a wide vitrification range. H. G. SCHURECHT.

The testing of chem. porcelain in England. J. GR. *Keram. Rundschau,* 28, 470–1 (1920).—To determine the defects the ware is soaked in 5 per cent eosin sol. for 18 hrs. By this means defects such as crazing, pinholes, porous bodies, etc., may be detected. The vessel is then washed in HCl and dried. Its resist. to sudden temp. changes is then measured. This is done by heating the vessel with a Bunsen burner, removing from the flame with a cold pair of tongs and placing on a cold porcelain triangle 6 times. The ware is then soaked for 12 hrs. in eosin sol. and examd. for defects. If no defects appear the vessel is subjected to six more heats. The resist. to high temps. is measured by heating to 950° C, at which temp. the glaze should show no signs of blistering or running. In the cleaning and wet heating test a dry vessel is heated to red heat, cooled and weighed. It is put in hot dil. acid (1 part conc. HCl and 1 part H_2O) for 12 hrs. It is then washed, dried with a towel and immediately put over a burner and heated to red heat. Upon cooling the weight should be the same as it was originally and the vessel should show no defects after soaking in eosin sol. To test the resist. to acids and alkalies the weighed vessel is filled with conc. HCl and heated over a water bath for 4 hrs. It is then reweighed. This same treatment is repeated using a 5 per cent Na_2CO_3 sol. and a 5 per cent NaOH sol. To roughly test the lead content in the glaze a drop of HF is applied to the glazed surface. The acid is evaporated by placing the dish over a steam bath and is then covered with a drop of H_2SO_4. A brown or black spot indicates lead, copper, etc., and should not appear on first-class ware. Lead or other reducible oxides may be also detected by heating to a red heat and passing a stream of H over same. If reducible the glaze will darken. H. G. SCHURECHT

Cone 7–9 porcelains. TH HERTWIG-MÖHRENBACH. *Sprechsaal*, **53**, 363–5 (1920).—Owing to the fuel shortage cone 7–9 porcelains are being substituted for the more fuel consuming cone 14 porcelains. Cone 7 porcelains vary in composition between the following limits:

$$\left.\begin{matrix} 0.5\ K_2O \\ .5\ CaO \end{matrix}\right\} 1Al_2O_3 5SiO_2 \text{ (Pukall) to } \begin{matrix} 0.65\ K_2O \\ .35\ CaO \end{matrix} \left\{ 1.97Al_2O_3\ 11.68SiO_2 \right. \text{ (Dorfner)}$$

Cone 9 porcelains vary between the following limits:

(*a*) RO $3Al_2O_3$ 14.45 SiO_2 to (*b*) RO 4.8 Al_2O_3 27 SiO_2

(*a*) This porcelain is very pretty but not very translucent. (*b*) This porcelain is very translucent. In France porcelains of the *a* type are fired at cone 14 at which temp. they become very translucent. A French body which matures at cone 9 is as follows:

$$\left.\begin{matrix} 0.8\ K_2O \\ .2\ CaO \end{matrix}\right\} 2.78Al_2O_3 12.74SiO_2$$

A Thuringian manufacturer makes a porcelain similar to type *b* which is fired at cone 9. Some well known Silesian and Bavarian manufactures use the following body which is fired at cone 9: RO $4Al_2O_3 18.7SiO_2$. If this body is ground for 24 hrs. at 23 r. p m. it matures at cone 9. All German hard porcelains mature at cone 9 if ground for 100 hrs. It is obvious that the SiO_2 and Al_2O_3 contents are not as important as one may think. A body of the following composition together with a little ZnO_2 makes an excellent porcelain at cone 9:

$$\left.\begin{matrix} 0.75\ K_2O \\ .25\ CaO \end{matrix}\right\} 3.5Al_2O_3 18.0SiO_2$$

One body of the composition RO 3.6 Al_2O_3 18.5 SiO_2 has a shrinkage of 10.6 per cent at cone 9 and was found very satisfactory for doll heads. The lower the acid content the better the porcelains stand up in firing. Glazes for cone 7 and 9 are as follows:

$$\text{Cone 7} \left.\begin{matrix} 0.2\ K_2O \\ .2\ MgO \\ .6\ CaO \end{matrix}\right\} 0.4Al_2O_3 3.5SiO_2 \quad \text{cone 9} \left.\begin{matrix} 0.2\ K_2O \\ .2\ MgO \\ .6\ CaO \end{matrix}\right\} 0.5Al_2O_3 4SiO_2.$$

Both of these glazes develop excellent greens which is impossible with cone 13 glazes. In firing colored glazes it is important to fire oxidizing. The following glaze develops a beautiful Victoria green:

$$\left.\begin{matrix} 0.4\ PbO \\ .45\ CaO \\ .15\ K_2O \end{matrix}\right\} 0.32Al_2O_3\ 2.95SiO_2.$$

In Thuringia the bodies are ground for 70–100 hrs. For glazing this ware hard tough glazes are required to prevent crazing. The bodies ground for 24 hrs. can be covered with softer glazes. Flint should be used in the place of quartz since it is much purer. The following bodies were found very promising for cone 7 porcelains, some having a very low shrink.

1.	$0.5\ K_2O$ $.5\ CaO$	$2Al_2O_3 10SiO_2$	9.	$0.5\ K_2O$ $.5\ CaO$	$2Al_2O_3 9SiO_2$
2.	$.5\ K_2O$ $.5\ CaO$	$1.9Al_2O_3 9.9SiO_2$	10.	$.63K_2O$ $.37CaO$	$2.3Al_2O_3 9.59SiO_2$
3.	$.5\ K_2O$ $.5\ CaO$	$1.8Al_2O_3 9.5SiO_2$	11.	$.50K_2O$ $.50CaO$	$1.8Al_2O_3 7.5SiO_2$
4.	$.8\ K_2O$ $.7\ CaO$	$1.84Al_2O_3 7.15SiO_2$	12.	$.50K_2O$ $.50CaO$	$1.8Al_2O_3 8.48SiO_2$
5.	$.65K_2O$ $.35CaO$	$2.41Al_2O_3 9.4SiO_2$	13.	$.65K_2O$ $.35CaO$	$2Al_2O_3 9SiO_2$
6.	$.50K_2O$ $.50CaO$	$1.6Al_2O_3 8SiO_2$	14.	$.50K_2O$ $.50CaO$	$1.6Al_2O_3 7SiO_2$
7.	$.50K_2O$ $.50CaO$	$1.7Al_2O_3 8SiO_2$	15.	$.50K_2O$ $.50CaO$	$1.5Al_2O_3 7SiO_2$
8.	$.50K_2O$ $.50CaO$	$1.9Al_2O_3 8.8SiO_2$	16.	$.50K_2O$ $.50CaO$	$2Al_2O_3 11SiO_2$

H. G. SCHURECHT.

Is Swedish quartz replacable by German sandstone in the manuf. of porcelain? ANON. *Sprechsaal*, **28**, 402, 412–3 (1920).—In Germany there are a number of sandstones which contain over 95.5 per cent SiO_2 and less than 0.05 per cent Fe_2O_3. This sand is used in the manuf. of high grade mirror and optical glass. It was found that the Swedish quartz has about the same SiO_2 as the sand and contains more Fe_2O_3 than the sand. In literature it is claimed that porcelains prepared with quartz sand have a gray color. Since this sand is purer than the Swedish quartz this color must be due to different optical properties of the sand which impart a grayish tinge instead of a white tinge as is obtained when Swedish quartz is used. Rieke and Endell (*Silikat-Z.*, **48**, 1920) found that upon firing Norwegian quartz once its sp. gr. was decreased from 2.65 to 2.38, while for Hohenbacher sand it was only decreased to 2.591 and only after firing 11 times was its sp. gr. decreased to 2.328.

H. G. SCHURECHT.

Brick and Tile

Requirements of quartz brick and mortar in England. ANON. *Keram. Rundschau*, **28**, 402–3 (1920).—The brick should contain not less than 94 per cent SiO_2 or more than 2 per cent CaO. The fusion should be cone 30 or better. Upon heating to cone 12 the brick should not show an expans. greater than 0.75 per cent. The quartz mortar should be finely ground and contain not less than 92 per cent SiO_2 and fuse at a temp. equal to that of the brick. H. G. SCHURECHT.

New selling methods in brick industry proposed. ANON. *Chem. Met. Eng.*, **23**, 1038.—A new card of price extras has been adopted by a number of leading producers of fire-clay and silica brick. Shapes are classified according to cost of manufacture and each class takes a percentage extra over the

base price. Thus the extra charge on any class of shapes automatically changes with any change in the base price. A large number of the shapes in common use have been classified according to the cost of production and it is expected that as further cost figures are obtained a complete list of all shapes in general use can be prepared. A. J. LAMBERT.

PATENTS

Brick machine. OLAF BRATNESS. U. S. 1,358,925, Nov. 16, 1920. A machine having a fixed mold and fixed end plate and a movable end plate, a rock-shaft to which the movable end plate is secured, a bottom plate for the mold secured to the rock-shaft, the rock-shaft being mounted for raising and lowering movement, a foot lever and lazy-tongs connecting the foot lever for raising and the rock-shaft.

Wall for brick-kilns. HALVER R. STRAIGHT. U. S. 1,360,245, Nov. 23, 1920. A kiln wall, formed of an inner and outer wall and a loose yielding filler between them, the inner wall being formed of a series of loosely laid bricks having their outer ends pointed or beveled, the bricks being laid in staggered relation, relative to each other, and the outer wall being formed solid. C. M. SAEGER, JR.

Cement and Lime

Manufacture of lime for chemical and metallurgical purposes. II. R. K. MEADE. *Chem. Met. Eng.*, **23**, 873–5; **III, 23**, 929–32.—A description of the applications of rotary lime kilns in burning stone and recovering spent lime. The advantages are great capacity, low labor and operations costs and utilization of spalls. Pulverized coal, producer gas, natural gas and oil are employed for heating rotary limekilns. The fuel requirements of a rotary kiln are from 2800 to 3500 B.t.u. or 400 to 500 lbs. of coal per ton of lime, 37 to 45 gal. of oil per ton of lime, 500,000 to 625,000 cu. ft. of natural gas per ton of lime. Pulverized coal and producer gas are the fuels commonly available. The advantages of pulverized coal over producer gas are: (1) more uniform rate of supply of fuel to the furnace and fuel of more uniform quality; (2) with powdered coal the loss due to carbon remaining in the ash is avoided; (3) it is possible to burn powdered coal with almost the exact quantity of air necessary for combustion, which is not possible with producer gas; (4) elimination of loss due to radiation of heat from the producer and piping system in manufacturing producer gas. The cost of gasifying a ton of coal in a mechanically stoked producer is $1.09. The cost of pulverizing a ton of coal is $0.71. The power required to operate a rotary kiln plant per ton of lime produced where pulverized coal is used is about 16 h. p. The cost of a rotary kiln lime plant of the best construction will be approximately $950 per ton of lime produced per day. The cost of producing lime in a rotary kiln plant in the middle eastern states at this time varies from $3.25 to $5.40. The waste gases, which leave the kiln at about 1300°F, can be used for heating boilers. A. J. LAMBERT.

Portland cement specifications. ANON. *Brit. Clayworker,* **29,** 27 (1920). —Brit. standard specifications for Portland cement, Report 12, 1920 contains a number of important modifications. (1) A paragraph has been inserted making clear that no cement to which slag has been added, or which is a mixture of Portland cement and slag, will comply with the specifications. (2) Provision has been made for sampling cement when stored in deep silos. (3) The sp. gr. test has been eliminated. (4) The aeration of cement before testing for setting time has been dispensed with. (5) A provision has been inserted permitting the deduction from the total lime content of the proportion of lime necessary to combine with the sulphuric anhydride present when calculating the lime ratio. (6) The medium and slow setting cements have been replaced by a grade having a minimum initial setting time of 20 mins., and a maximum final setting time of 10 hrs. A minimum final setting time is not now specified. (7) The clause relating to the supply by the vendor, free of cost, of a certificate that the cement has been tested and analyzed and complies in all respects with the specifications, has been modified to provide that if such a certificate is required it must be so specified at the time of purchase. It is stipulated that samples for testing are to be taken from 12 different positions of a heap or from 12 different bags. Six tests are required to be carried out whose results should comply with the following conditions: (*a*) *Fineness.*—100 g. are sifted for 15 min. on each of the following sieves: (1) 180 $\times$ 180 mesh, to leave a residue not to exceed 14 per cent. (2) 76 $\times$ 76 mesh, with not more than 1 per cent residue. (*b*) *Chem. Analysis.*—Insoluble residue not to exceed 1.5 per cent; magnesia, 3 per cent; and total S calculated as sulphuric anhydride, 2.75 per cent. The total loss on ignit. to be less than 3 per cent. (*c*) *Tens. strength* (*neat cement*).—Test briquettes to be kept damp for 24 hrs. after gauging, after which they are to be removed from molds and submerged in fresh water at a temp. of 58–64°F 6 briquettes to be tested for breaking strength at 7 and 28 days respectively. After 7 days breaking strength not to be less than 450 lbs. per sq. in. section, and an increase to be shown at 28 days and not to be less than that calculated by the following formula:

$$\text{Breaking strength at 7 days} + \frac{40{,}000}{\text{Breaking strength at 7 days}}.$$

(*d*) *Tens. strength* (*cement and sand*).—Briquettes to be in proportion of 1 part of cement to 3 parts of standard sand, each by weight. Conditions for setting are the same as for neat cement. Breaking strength at the end of 7 days to be not less than 200 lbs. per sq. in. section. For 28 days breaking strength to comply with conditions similar to neat cement. (*e*) *Setting time.* —Initial setting time to be not less than 20 min. and final setting time no more than 10 hrs. These times are to be determined by Vicat needle apparatus. (*f*) *Soundness.*—This is to be tested for by the Le Chatelier method. The expans. is not to exceed 10 mm. after 24 hrs. treatment. After 7 days it shall not exceed 5 mm. H. G. SCHURECHT.

ACTIVITIES OF THE SOCIETY

Actions of the Board of Trustees

December 10. It was voted that the price of the Collective Index to the Transactions be $1.50 postpaid.

December 10. It was voted that Dr. E. W. Washburn be appointed Editor of the Journal for 1921, at a salary of $125.00 a month.

December 28. A provisional draft of By-Laws for any Division of the Society, recommended by the Committee on Rules, was approved by the Board.

December 28. It was voted to allow the Enamel Division the sum of $20.00–$25.00, in addition to the regular allottment, for the operations of the Division in a membership campaign.

New Members Received during December

Associate

Ahlswede, R. B., 1406 N. Spring St., Los Angeles, Cal., Secretary, California Metal Enameling Co.

Coates, William W., Jr., 313 East Springfield St., Champaign, Ill., Student, University of Illinois.

Kahn, Harry J., Zanesville, Ohio, Assistant to Director, American Encaustic Tiling Co.

Koupal, Walter G., Creighton, Pa., Pittsburgh Plate Glass Co.

Merritt, L. M., 586 E. Long St., Columbus, Ohio, Ceramic Engineer, Barnebey-Cheney Engineering Co.

Post, Albert H., Waterville, Conn., Superintendent, Gordon Electric Manufacturing Co.

Powell, R. E., 8700 S. State St., Chicago, Ill., Chief Engineer, Federal Electric Co.

Slobodkin, S. H., 146 Condor St., East Boston, Mass., Boston Pottery Co., Inc.

Smith, R. G., Fort Worth, Texas, Plant Manager, Acme Brick Co.

Swope, H. J., Quincy, Ill., Business Manager, Economy Enameling Co.

Taylor, R. P., Roseland, Nelson Co., Va., Superintendent, Klimax Kaolin Co.

Corporation

Portland Stove Works, Portland, Oregon.

JOURNAL
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AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 4 **February, 1921** **No. 2**

EDITORIAL

CERAMIC ABSTRACTS

Beginning with the literature of the year, 1921, the Journal will endeavor to extend the scope of its Abstract Division so as to cover all the literature of the world which contains material of direct interest to the ceramic industries. Through the work of our own corps of abstractors supplemented by coöperative arrangements with other abstract journals we hope to make the Abstract Division of the Journal an exhaustive summary of the world's ceramic literature.

If a sufficient number are interested, the Journal is also prepared to offer, at cost, to members of the Society, a special Abstract Reprint Service which will enable members of the Society to assemble and keep up to date a card catalogue of any ceramic subject in which they are specially interested. This service will take the form of supplying monthly reprints, in duplicate (if printed on both sides of the paper) or singly (if printed on one side only), of the abstract division of each number of the Journal. The desired abstracts can thus be clipped and pasted upon cards of any desired size.

It is estimated that this service could be given at a cost of \$3.50 per year to each of 50 subscribers and \$2.50 per year to each of 100 subscribers. Members interested in securing this service are requested to communicate with the editor not later than March 20. The service would begin with the February Journal and would thus include abstracts of all papers beginning with the year 1921.

Beginning with the present number, each original paper published in the Journal will be preceded by an analytical abstract prepared in accordance with a system devised by G. S. Fulcher of the Corning Glass Works. The abstracts of the papers appearing in the February, March, and April numbers of the Journal will be made by Dr. Fulcher, in order to serve as examples of this system of abstracting. Thereafter, it is hoped that authors of original papers will prepare their own abstracts. An explanatory description of the analytical system of preparing abstracts will be published in an early number of the Journal. These abstracts will take the place of the customary authors' summaries and they will be included in the proposed Abstract Reprint Service, if there should be sufficient demand for that service to justify starting it.

ORIGINAL PAPERS AND DISCUSSIONS

ANCIENT AND MODERN METHODS OF GLASS MANUFACTURE*

By H. L. Dixon

ABSTRACT

Progress in appliances and methods of glass manufacture since 1877.—The article contains a brief summary of the personal experiences and observations of one who for over forty years has actively participated in the development of appliances and methods used in various branches of the glass industry.

It must not be supposed, because of the subject of this paper, that it is necessary or that it is the intention of the writer to review the glass business and its methods of manufacture from the time of its discovery. That would indeed be tiresome and unprofitable, because there are many publications in which the discovery and ancient history of glass manufacture may be read. It is intended only to cover the personal experiences and observation of the writer for a period of a little over forty years of actual participation in the development and improvement of the appliances and methods used in the various branches of the glass industry. A careful comparison of the equipment and processes in vogue during that period will amply justify the use of the word ancient in the title.

In reviewing the progress made in the development of the various appliances and methods employed in the manufacture of glass, it is difficult to avoid indulging in personalities and the mention of many eminent men, leaders in the promotion of the industry, some of whom are still living, and, inasmuch as this is intended to be a review of the improvement in methods of manu-

* Read at the meeting of the Society in Philadelphia, Feb. 23, 1920.

facture rather than a history of the business, it will be impossible to mention a great many of the prominent and capable men deserving of a permanent record in the history of the glass business. In the preparation of a full and complete record of development and improvement in the equipment and processes employed during this period, the difficulty encountered is not the discovery and recital of sufficient crucial and epoch making discoveries that are of interest today, but rather the impossibility of covering the subject completely in the brief manner necessary to avoid being too voluminous and tiresome.

Making Glasshouse Refractories in Early Times

The writer began his business career in 1877 with his father and uncle and one or two others composing the old firm of Thomas Coffin & Company, which had started in business in 1860 as manufacturers of glasshouse pots, furnace blocks and other refractory materials required by the glass trade of that time. This company was the only one engaged in that line of business, but it was the habit of many of the glass manufacturers of those days to make their own pots and refractory materials. Even then the elder members of this company were invariably consulted about the proper dimensions and construction of glasshouse furnaces, of which they had an expert knowledge acquired from a long experience. There was, however, at that time, no such business as furnace building. Thomas Coffin & Company manufactured all of the furnace blocks the trade required in a room 40 by 60 feet in size and had only one kiln, 16 by 18 feet, in which to burn them. It was the custom of glass manufacturers in those days either to manufacture their own furnace material or to purchase it from this company and then employ two or three of the expert furnace builders, bricklayers of exceptional ability, to do the construction work. Plans and specifications for such work were absolutely unknown, it being the habit to copy some other successful furnace and leave all of the details of construction to the brick mason, after obtaining some advice as to the proper diameter, spring of crown arch, size of the eye or fire box, etc. It was the custom in those days for the pot manufacturer, with a sufficient number of men, to deliver the pots to the glass factory,

place them in proper position in the furnace for preheating or in the pot arch as desired. Participation in this work brought the writer in contact with many of the older manufacturers of that day and gave excellent opportunity for observation. It is a delight and satisfaction now to recall how these real pioneers in the glass industry delighted to explain all of the intricacies of the glass business, including the operation of furnaces, and incidentally to recite how much better they were doing, how much more glass they were melting, than their competitors—a valuable school of instruction for a young man, scarcely appreciated at that time but which today is the source of many fond recollections of eminent and capable men of their time who have long since passed away, and which was the source of much profit in the development of after years.

Early Direct Fired Furnaces

The direct firing type of coal burning furnaces was universally used in those days and, because of the splendid fuel obtainable at a very low cost, there was very little inducement for the investment of capital in fuel saving furnaces. All flint or crystal, both lime glass and lead glass, was melted in covered pots in circular furnaces having a fire place or eye in the center. Many of these were teased, or stoked, through a tease hole in one of the pillars between the pots, from the glass factory floor. Afterwards an improvement was made by the design of a furnace in which the fuel could be pushed from the cave or basement into the eye of the furnace, and afterwards this was still further improved by the use of what was known as the bucket teaser. This was a mechanical device that was placed in the cave or basement immediately below the eye of the furnace. It was charged with coal and by means of gears and mechanical contrivances the coal was pushed up through the center of the fire bed, the grate in that case surrounding the bucket. This proved to be a very efficient, hot running furnace and came into use about 1878.

These furnaces were built of clay blocks for the pillars and crown, similar to those in use today; the eye was lined with burnt blocks of large dimensions, and the benches or sieges were made of bulk clay, similar to that in use at the present time. The

flues were distributed around the outside of the circle, passing through the breastwalls in front of the pots and up into the cone or chimney, over the furnace which supplied the draft necessary for the operation of the furnace.

Late in the seventies John Nicholson, Jr. introduced what was known as the Nicholson gas furnace, which was a modification of a French invention, by erecting one of this type at the works of the Rochester Tumbler Company, Rochester, Penna., and this proved to be a marked improvement over the ordinary type of furnace. It was particularly designed to use a cheap grade of fuel—fine slack coal—by converting it into gas and providing means for its complete combustion in the eye of the furnace. This furnace employed three of the old type Siemens natural draft producers located in the basement of the factory, in which the well known restricted grate area of the original Siemens producer was employed, and the fuel was fed through hoppers on the top of the producers. A continuous distillation of gas was obtained which passed through horizontal flues leading to the eye of the furnace, and the air utilized for its combustion was conducted around the walls of the producers and flues as well as the lining of the furnace eye, finally entering the eye near the bench level, where it met the gas from the producers and an approximately perfect combustion was obtained. The results were very economical, in that a saving in cost of coal was effected, and the temperature of the furnace was maintained more uniformly and at a higher degree, so that the production was materially increased. This furnace became very popular and a large number of them were constructed in the ten or twelve years following this first development.

About the same time, in the late seventies, Mr. J. J. Gill of Steubenville, Ohio, introduced what was afterwards known as the Gill furnace, which was an improvement and modification of the Boetius furnace used in Europe. This furnace was also designed particularly to use a cheap grade of coal—fine slack coal—and employed two producers of rather large dimensions, one on each side of the eye of the furnace in the basement or cave immediately under the bench, the coal being fired through tease hole doors in the front walls. The gas distilled from the coal in these producers

passed directly through apertures or ports in the back walls of the producers into the eye. The air for combustion was passed around the walls and crown arches of the producers, as well as around the walls of the eye, becoming heated by induction and absorption and finally being introduced into the eye just above the gas ports below the level of the siege or bench. This proved to be a great improvement over the old type of direct fired furnace and resulted in an increased production because of a higher and more uniform temperature, as well as a reduction in the melting cost because of cheaper fuel.

In the early eighties what is known as the deep eye furnace was developed in New Jersey and was particularly adaptable for the use of the semi-bituminous Georges Creek and Cumberland coals commonly used in that district. This consisted simply of an eye of greater depth than usual for use in flint glass furnaces in which the fuel bed was far enough below the level of the bench or siege to permit the introduction of a secondary supply of air above the fuel bed and in close proximity to the level of the bench, to accomplish the combustion of the volatile gases escaping from the fuel bed below. This was generally operated in a manner similar to the operation of a gas producer for the purpose of liberating the volatile matter and burning it above where it came in contact with the air entering a circular series of ports around the eye, after having been conducted around the walls of the fire bed absorbing such heat as it may by induction through the walls of the eye. This proved to be a very economical fuel burner and one that some manufacturers thought was as effective and economical as either a Gill or Nicholson furnace. This deep eye type of furnace was used extensively in the western bituminous coal district and is in use today in a number of factories where natural gas is not available, and where suitable coal is obtainable within a reasonable cost.

Expansion of the Glasshouse Refractories Business

Owing to the large number of deep eye, Gill and Nicholson furnaces erected within a comparatively few years, the demand for furnace blocks of good quality and special shapes was very much

increased, and necessitated a very large addition to the capacity of the block manufacturers.

In 1878 and 1879 there was an unusual boom in the glass manufacturing industry, especially in tableware and all lines of flint glassware. Idle furnaces were put into operation and new ones were constructed, with the result that the one pot manufacturing company existing at that time could not supply the pots and sufficient of the refractory materials demanded by the suddenly increased business. This led to the organization of the Pittsburgh Clay Pot Company by a number of the glass manufacturers who, for the first time, realized the risk, uncertainty if not danger, of depending upon the one company for their supply of these materials. Since that time the great increase in the business of manufacturing glasshouse pots, furnace blocks and other refractory materials is well known, and it has become one of the largest industries in the country. Glass manufacturers, as a rule, have entirely abandoned the manufacture of these supplies for themselves and depend upon the various institutions engaged in that business for their requirements.

Early Types of Pot Furnaces

In the seventies all window glass and green and amber bottle glass was made in open pot furnaces of the most primitive, direct firing type. They consisted of a square, or rectangular furnace chamber, erected over a cave or basement, the grate extending the full length of the furnace and discharging its ashes into this cave, which was also arranged to supply the air passing through the grate for combustion. The furnaces in the Pittsburgh district, which embraced quite a wide area, in those days were all built of sand stone obtained from quarries at Perryopolis, Pa. The benches or sieges were made of two layers of great slabs of sandstone, provided with wide open joints for expansion. The walls and crown arch were built entirely of the sandstone; the arch being so constructed that, while it was fully 12 inch in thickness, the stones only had a bearing of about 4 inch on the top and an open joint on the bottom of 3 to $3^1/_2$ inches to provide for expansion, the arch having to rise to such an extent that the lower joints would come together and close after the furnace was heated.

It was the custom in those days for the Porter Brothers at Perryopolis to quarry and cut the stone for all of these furnaces during the period of furnace operation, and ship them so they would arrive in time for the construction of the furnaces during July and August of each year, when all glasshouse operations ceased for a period of at least two months. Porter Brothers, during that time, would erect the various furnaces and have them ready for operation in September, there being no clay material employed except the outside casing to back up the stone lining of the furnace walls. In other districts, such as New Jersey and New York, it was the custom to build the furnaces of unburned clay blocks of a mixture of Jersey sand and German pot clay, and frequently they were simply pounded over a wooden form while the clay was in a plastic state, being cut with a wire into sections to take care of the shrinkage and avoid cracking as much as possible. Many of these furnaces were not provided with any stacks but were constructed in the center of a building with a very high conical shaped roof with a cupola at the top. When the melt was being made all doors and windows were closed so that the draft would pull through the cave or tunnel beneath the furnace, through the grate, and out through the ringholes or flues of the furnace, up through the cavity formed by the high roof. Naturally, this method of firing resulted in an enormous loss of fuel and much smoke and soot. The firing of the coal was through the ends of the furnace and the very best grades of lump coal were used. In New Jersey and some other sections they used furnaces with a forced draft which enabled them to use the semi-bituminous coal of the Georges Creek and Cumberland districts, instead of the highly bituminous gas coal of western Pennsylvania.

Previous to 1880 very little had been accomplished in the introduction and application of fuel saving devices for the obvious reason that the best of fuel in most of the glass manufacturing localities was obtainable at a very low price. Of course, various attempts have been made to operate furnaces that would use the cheap grade of fuel, known as slack coal, which at that time was a drug on the market and was obtainable in abundance at the bare cost of mining and delivery. The Nicholson, Gill and deep eye

furnaces were particularly adaptable for the use of this cheap coal; but, while they reduced the cost by using cheaper fuel, they did not reduce the quantity required in a given time, nor did they in any way reduce the labor or skill required in the operation of direct fired coal furnaces.

Introduction of Regenerative Pot Furnaces

Although the well-known Siemens regenerative type of gas furnace had first been applied to the glass manufacturing business in England in 1861, it was not until many years after that it was made use of by the manufacturers of the United States. According to the United States Census Report of 1880 the Division of Glass Manufacture by Joseph D. Weeks, published in 1884, gives the number of Siemens regenerative pot furnaces in operation in 1879 as follows: Great Britain 12, France 22, Belgium 6, all other countries 31. The above covered plate glass, window glass, bottle glass and flint glass manufacturers. Siemens furnaces with daily melting tanks: Great Britain 6. Siemens furnaces with continuous melting tanks: Great Britain 4, France 10, Belgium 1, other countries 3.

It can be seen from this report that, while the Siemens regenerative principle had been extensively applied to the iron and steel business, it had not been adopted by many of the glass manufacturers. In 1866 or 1867 the first Siemens regenerative furnace was applied to the glass business in the United States. This was erected by the engineers of Sir William Siemens, the inventor of this type of furnace, at the O'Hara Glass Works of James B. Lyons & Company on 30th Street in Pittsburgh. It proved to be a failure because of the wrong application of the producer gas to the furnace chamber. At that time the old type of natural draft producer was used in connection with the long cooling tube supposed by the Siemens engineers to be necessary, and the air and gas ports were so constructed that the flame was introduced into the furnace chamber in a horizontal direction above the level of the pots. Great difficulty was experienced in keeping the furnace supplied with gas from the producer because of the accumulation of soot in the cooling tube and flues leading to the furnace. In the application of this principle to the iron and steel

furnaces, this trouble was not considered serious, because they could stop at any time between melts or between heats and remove the soot from the cooling tube and other flues, but in a glass melting furnace where pots were employed this would result in damage to the pots and it was necessary to maintain a continuous supply of gas to preserve a uniform temperature in the furnace that would safeguard the pots. The other difficulty, and the one that was most fatal to the successful operation of this furnace, was the fact that the intense heat of the flame above the pots destroyed them by melting in the crowns, so that it was impossible to maintain a melting temperature and at the same time preserve the pots. While it was not realized at that time, it subsequently became apparent that to operate with such a furnace it was necessary to employ the well known reverberatory principle where the fuel was introduced vertically through the bench or siege in the middle of the furnace within the circle of pots, so that the force of the flame and intense heat would be spent against the crown arch of the furnace and rebound in such a way as to surround the pots and heat them without injury. Inasmuch as this was not understood at that time, this furnace, after a little over one year of operation, was abandoned and the entire equipment torn out for the purpose of restoring the old type of direct fired furnace.

Regenerative pot furnaces are now extensively used with raw producer gas, clean producer gas and natural gas, and have been so improved that greater economy of fuel is obtained as well as largely increased production. These furnaces are built for 14, 16, 18 and 20 pot capacity, the pots being of such dimensions as to contain from 3000 to 4000 pounds of glass; and, where working conditions will permit, the melts are made in about 24 hours after filling.

Early Tank Furnaces

While the continuous melting regenerative gas fired tank furnace was first introduced in England early in the sixties, it was not until 1880 that the first furnace of this type was built in the United States. This was built by the engineers of Sir William Siemens at Poughkeepsie, N. Y., and in 1882 the second furnace

of this kind was erected at La Salle, Ill. While much trouble was experienced in the operation of these furnaces, principally because of lack of skill and training, they were really the pioneers and, while only common green and amber bottle glass was made in them, they demonstrated the adaptability of this type of furnace for various lines of glass manufacture. Information gained from the operation of these tank furnaces enabled William F. Modes and others to design a modified form of Siemens regenerative tank furnace which they afterwards installed at the works of the Streator Bottle & Glass Co., Streator, Ill. and subsequently in a number of other factories for the manufacture of bottles. It was in 1884 and 1885 that the first successful continuous melting tank furnace for the manufacture of window glass was introduced at Streator, Ill. by the Streator Window Glass Company.

Natural Gas and the Glass House Migration

While the furnaces above mentioned were operated with raw producer gas made in the old type of Siemens natural draft producers, it was at this propitious time—1883 to 1885—that natural gas was first utilized as fuel for the manufacture of glass. The first use of natural gas in a glass furnace was in 1883 at the works of the Bradford Window Glass Co. at Bradford, Pa. Its first application was not successful and it was not until 1885 that the furnace was properly arranged to utilize this fuel effectively. The first introduction of this fuel to a flint glass melting furnace was made at the Riverside Glass Works, Wellsburg, W. Va.; and it operated successfully and economically from the beginning. The discovery of this valuable fuel in such abundance, its cheapness and ease of application without serious alterations to the furnaces in use at that time, caused a complete revolution in the glass manufacturing industry; evolution might be a better term to use but those who can remember the rapid changes and enormous increase in the number of factories, their migration from place to place, will agree that it is difficult to find a term that properly expresses the rapid development of this industry, due solely to the abundance and cheapness of natural gas. Its adoption and use by the manufacturers of the Pittsburgh district was attended by what is now understood to have been criminal

carelessness and waste; the pipe lines were carelessly laid in the haste of rival gas companies to be first in the market, and ridiculous inducements were offered manufacturers to use it on a contract basis that was an incentive to waste it, and it was not until some years afterward, when it was sold by meter measurement, that, even with the low price prevailing at the time, was there any encouragement or inducement to economize in its use. After comparatively few years of revelry in the super-abundance of this most ideal natural fuel, the fields in close proximity to the Pittsburgh district began to be exhausted, and then commenced the great migration to other fields. In 1885 the great Karg well was struck in Findlay, Ohio, and the boomers of that town immediately began to offer inducements to glass manufacturers to move their plants, or build new ones in that vicinity. They offered free land for a factory site, natural gas for fuel absolutely free and, in many cases, as a further inducement, a cash bonus to assist in building the factories. Gas in the meantime had been discovered in other localities contiguous to the Findlay district and in comparatively few years a very large glass industry had been built up in that section. The same waste and disregard of economy prevailed here that was practiced in the Pittsburgh district, with the result that the supply was rapidly exhausted, and the manufacturers began to look for other locations.

In the meantime, natural gas had been discovered in Indiana in the neighborhood of Marion, which was afterward developed into a very wide, extensive and prolific field, and the booming of numerous towns was here repeated—free land, free gas and cash bonuses induced the establishment of a large number of factories in districts where hitherto the glass business had been unknown. The experience in this district was similar to that of Findlay, Ohio, and Pittsburgh and resulted in a number of the factories moving to the gas fields of Kansas. Upon the exhaustion of the gas in Kansas district, the industries moved to the gas fields of Oklahoma and Texas, where they are still holding on and operating with the hope that they have at last found an inexhaustible fuel supply. There are factories in this district which were built by parties who originally left the Pittsburgh district and have moved to each succeeding gas field. There are few who realize the extent of this migration or evolution in the glass business.

In the Pittsburgh and Ohio River districts a great many of the old established glass manufacturing companies have actually gone out of business, largely due to the unusual competition of cheap natural gas and methods employed by newly created manufacturing institutions unfamiliar with the glass trade. There are many conservative business men who are of the opinion that the use of natural gas in this industry has not been of permanent benefit to those engaged in the business, although great benefit has resulted in the improvement of the quality of the glass produced as the result of the use of this fuel.

The state of West Virginia appears to be the most prolific field and source of supply at the present time and is serving a very wide district outside of the locality where the wells are located. Pittsburgh today depends very largely upon this district for its fuel. A very large glass industry has been established in this state and the manufacturers have the advantage of being located where there is an abundant supply of bituminous coal, so that the substitution of coal gas producers in this district will obviate the necessity of moving to other localities when the natural gas is exhausted.

From the city of Pittsburgh alone thirty-three glass manufacturing establishments have either moved to other localities or have gone out of business entirely; thirty of these were from the "South Side" alone. In the Findlay, Ohio, district there were at one time over thirty glass factories in operation; today there are none; all having been abandoned or moved to other localities. In the Indiana district, while many of the factories have moved elsewhere, a number of them have adopted the use of gas producers and still maintain their business on a permanent fuel basis by using coal.

Naturally, this great movement of glass factories and the establishment of new ones, together with the improvements in furnaces, the adoption of the continuous melting tank and other innovations furnished the opportunity for the establishment of the business of building glasshouse furnaces and appliances, and it was in 1884 that the writer first engaged in that business.

(*To be continued*)

THE MANUFACTURE AND TREATMENT OF GLASS MELTING POTS*

By W. K. Brownlee and A. F. Gorton[1]

ABSTRACT

Manufacture of glass melting pots.—The raw materials used, the methods of grinding and mixing the raw clay and grog, and the way in which pots are built and dried are *briefly described* for the purpose of impressing glass makers with the amount of labor and care involved. At present only one grade of pot is made; but the difficulty of getting a pot suitable for all kinds of glass suggests the desirability of making special grades of pot for use with specified kinds of glass.

Proper treatment of pots by the glass maker.—The authors emphasize the importance of gently handling pots and of storing them in a warm and dry place. The precautions to be taken in preheating pots in arches are discussed at length for this is the critical period in the life of the pot. The batch should be properly crushed and mixed and should either be preheated or loaded in gradually; and the furnace temperature should be carefully regulated. It is particularly urged that the technical treatment of pots in the glass be entrusted to a man trained in ceramics and physical chemistry.

Arches for heating glass melting pots.—After discussing the usual design the authors *suggest improvements* as to fire box locations, construction of walls and door, etc.

Introduction.—The subject of glasshouse refractories and their treatment in glass plants, despite its obviously fundamental importance in the industry, has received as little attention in the publications of the American Ceramic Society as almost any other topic that could be mentioned. In the 19 volumes of the Transactions, there are two papers dealing with the subject, both of a general nature, and not calculated to afford direct assistance to either the pot manufacturer or the glassmaker. Periodicals devoted to the glass trade are singularly innocent of information on this subject, and perhaps the only publication of recent times devoting a fair amount of attention to pots and their usage is the (British) Journal of the Society of Glass Technol-

* Read at meeting of the Northern Ohio Section of the Society, June 7, 1920.

ogy. This state of affairs is to be deplored all the more because there was never a time in history when the need of sincere coöperation, mutual criticism and common counsel of the pot manufacturer and the glass maker was more urgent than at the present day. Many conditions that have developed since 1915, which are traceable to the War and our participation therein—such as the disappearance of German clay, the search for a substitute among American bond clays, the demand for greater production which caused our glass manufacturers to speed up, incidentally forcing pots both in the arch and in the furnace, and maintaining higher furnace temperatures; and, finally, the production of heat-resisting glasses of the Pyrex type, boiler gauge tubing, "high-pressure" glass, etc., all of which require not only higher temperatures (close to 2800 degrees Fahr.) but also longer melting period—all of these conditions certainly make apparent the need of research and the publication of the results of such investigation in a way calculated to reach all manufacturers in the industry.

Though the writers' purpose is to emphasize the need of care in the treatment of pots after they leave the pot factory, methods used in their manufacture will be briefly touched upon, with the idea of convincing the glassmaker that an article on which so much tender care is lavished in its early stages is deserving of the very utmost in the way of intelligent treatment in its period of usefulness. Certainly the manager of a glass factory labors under a very serious handicap if he is not thoroughly acquainted with the possibilities and peculiarities of the clays entering into the makeup of the pot, for the success of his enterprise depends as much on the average length of life of his pots as on his ability to produce good glass. When a pot fails prematurely (say, before the third melt), if all elements of cost are taken into consideration, such as the cost of pot and contents, of fuel and labor, and the consequent loss of production before another pot can replace the damaged one, the total may represent a loss of $800.00; hence it is clear that the glass manufacturer will profit greatly by using every possible precaution calculated to prolong the life of the pot.

Raw Materials.—The raw clays and burnt material entering into the pot batch should be selected with care, so that the finished pot may possess certain definite physical properties, such as (1) low drying shrinkage, permitting of safe drying; (2) good dry strength (tensile or transverse strength), permitting of safe shipment to the glass plant; (3) low burning shrinkage; (4) a structure open enough to withstand the changes of temperature incident to filling and melting operations; yet sufficiently dense to guard against corrosion; (5) ability to withstand high temperatures under load. The old German clay, as Bleininger has recently pointed out, was valuable not alone for its exceptional drying behavior and its open-burning nature, but also because of its low burning shrinkage in the region 2000 degrees—2500 degrees Fahr., which corresponds to the interval between the highest temperature reached in the arch and working furnace temperature. In seeking a suitable American bond clay, it has been common experience that it is easy to procure a plastic, tough clay, but the drying and burning shrinkage is invariably high, so that it has been necessary to mix with such a clay a proportion of sandy, open-burning clay, of low shrinkage. The result, of course, is not equivalent in all respects to the German clay, but undoubtedly is superior in certain respects such as refractoriness; and in actual service such mixtures have yielded creditable results.

Raw clays should be as free from iron and sulphur as possible, and low in carbonaceous matter. As regards the burnt material, "potshell" is still in common use, and a certain amount of calcined clay is added. There are various objections to the use of "potshell," which at best is very variable stuff, owing to the fact that different parts of the pot are subjected to widely different temperatures and therefore reach different conditions of porosity. Potshell should be thoroughly dried, and might with advantage be "rattled," to remove accumulated dirt. Great care is necessary in rejecting black, overfired portions. It is hard to get men nowadays to pick potshell, and the cost of the cleaned material is mounting rapidly, so that it may not be long before pot manufacturers abandon this practice.

Grinding.—The grinding of the burnt stock or grog is an important operation; and the mills should be of a type that will produce the proper amount of fines, so that the raw or bond clay acts as a binder on the largest and smallest particles alike, rather than becoming a filler of voids in which there are no fine particles of burnt clay. Transverse strength tests made on dried bars readily show the influence of the proportion of fines on the strength, and this as well as other points are well discussed in papers by Kirkpatrick and Fulton and Montgomery.[2] It is also known that the proper percentage of fines used to obtain good tensile strength gives to the clay mass the quality of resistance necessary to best withstand corrosion. The pot manufacturer must ever be mindful of the glassmaker's practice, which in a way must govern the degree of density that will enable the pot to undergo the user's treatment. The denser the structure of the pot, the greater is the necessity of more careful temperature control in pot arch and melting furnace. We can build a pot that will permit of rapid heating in the arch, such as arching in four days, and such a composition would not be quickly affected by the filling of cold batch, but the resistance to corrosion is lessened proportionately to loss of density. Hence we must strike a happy medium wherein both requirements are satisfied.

Mixing.—When the required amounts of previously ground raw clay and grog have been weighed, they are carefully mixed together. This is best done in a mixer whose blades are fixed to a horizontal shaft. A concrete mixer or other rotating device will not do the work because, as is known, the rolling motion causes a separation of the coarse from the fine particles. From the mixer the material is elevated and distributed to an open top pug mill, where sufficient water is added to make the whole fairly soft. It is important that little or no water be added after this first pugging, for if the batch is too stiff it will not age properly, and when much extra water is added in the final pugging it does not soak into the mass. The ageing period depends on the nature of the clay—some clays develop maximum strength and plasticity after three weeks' storing, others require months, and in certain cases there seems to be a decrease in strength after the first few

weeks.[3] From the storage bins the clay is conveyed on an endless belt to a wet pan, where a final tempering is given before putting it through a roll machine which cuts it into rolls or clots of a convenient size for the potmaker to handle.

Building.—Little need be said of the operations required in building the pot, since this subject has been adequately discussed elsewhere.[4] Suffice it to say that the pot is built up in layers, the time interval between applications being long enough to permit each layer to stiffen sufficiently to support the weight of the next. Extreme care and skill are used in joining the clay together; and it is of the utmost importance to have adjacent portions of the same degree of softness, otherwise mutual contraction will result in a crack, or at least set up strains which will bring about a leak later on. It is necessary to cover the upper surface of the clay with damp cloth each night as otherwise the natural drying will form a crust on the top.

Drying.—The drying period has always been long in this country—a matter of four to six months or even a year—and the English practice seems to have been in agreement with this. However, modern demands on production are such that the old, slow method is fast being crowded out, and modern science has developed in the so-called "humidity drying" a means of shortening this stage of the pot's life. Already pots have been dried safely in thirty days, even without artificial circulation of the air, and this record may be exceeded in the future.

Modern drying practice demands a careful regulation of the humidity, temperature and circulation of the air of the pot room, and to secure absolute control of these elements, automatic regulating devices are imperative, also recording devices making a permanent record on a chart. If left to itself, the air of a pot room adjusts itself to changes in the state of the clay, that is, at the start, when the room is full of wet clay, the humidity is high (80 per cent or more), and the temperature is greatest at the ceiling whereas the moisture is greatest near the floor. As the pots dry out, the humidity naturally decreases till at the end it reaches 40 per cent more or less, depending on the season of the year. In some plants it is customary to cover the pots completely

with burlap sacks till they are out of danger. How drying proceeds under these conditions is a mystery to many people; but the principle is simple and was first demonstrated by Washburn,[5] the water vapor being attracted downward to regions of greater humidity, thus preventing saturation of the air adjacent to the clay.

Much remains to be done in discovering the possibilities of humidity drying—much information ought to be gained by logical, carefully controlled experiments, and it is a pity that in some cases this has been subordinated to a policy, on the part of the manufacturer of drying equipment, of guaranteeing to dry the article in an exceedingly short time, when as a matter of fact he has no evidence to back up such a claim. It has been shown that valuable results are obtained by distributing the heating pipes evenly over the floor, for this does away with overhead coils and even coils under the windows, effecting great economy, and it also produces even conditions as to temperature and humidity from floor to ceiling. Where temperatures under 80 degrees Fahr. are employed, pots can be dried safely in five weeks after completion by maintaining a minimum relative humidity of 65 per cent, and certain evidence shows that better pots are produced by preserving a *constant* humidity of 65–70 per cent from start to finish.

Shipping.—Pots must be packed carefully in the freight car, as they travel sometimes 1000 miles to their destination, and switching engines are no longer respecters of the sign "glass melting pots"—"switch and couple carefully." It is best to make a crate around each pot, with sufficient padding of hay under the bottom and around the walls to permit a slight give and take. Cleats nailed to the floor, used to prevent horizontal shifting, sometimes cause shearing of the pot bottom, when the train is jolted excessively.

Pot Storage.—Upon arrival at the glass factory, the pots are removed from the car and carried to the store-room. Gentle treatment is necessary on all occasions when pots are moved, as the concrete and brick pavements or floors over which they must travel are usually far from smooth, and carriages of the

springless type are invariably employed. It is well to point out that the bearing surface of the pot carriage or fork must be ample to preclude the danger of straining the pot. On a few occasions the writers have seen a pot fail due to longitudinal cracks in the bottom[6], which developed where the pot was supported by the fork used in moving the pot from the arch to the furnace.

The space devoted to storage should at all times be warm and dry, and must afford complete protection from the weather. It is unfortunate that some glasshouse managers have little regard for the welfare of their pots and apparently do not think it worth while to provide a special store-room, but set them here and there in stray nooks and corners not already occupied by packing cases, barrels or other impedimenta of the basement. Under such circumstances the pots may suffer from chance leaks in overhead piping, or at any rate take up a certain amount of moisture from the air. The place best adapted for storage is undoubtedly the space near the substructure of the furnace or basement, as this is at all times warm and dry. The benefits to be derived from proper care at this stage are more evident when one considers that there are many occasions when it is not practical to cool a pot arch below 110 or 120 degrees Fahr. (this is especially true of "twin" arches, or those with a common wall), hence it is clear that the pot is better able to withstand such rapid initial heating if it has been previously held in a dry place at about 85 or 90 degrees Fahr.

Pre-heating of Pots in the Arch.—We come now to the most critical stage in the life of the pot, the period which largely determines whether the pot is to fall ingloriously after a few melts, or linger on and on for perhaps 60 melts. The heating of the pot in the arch is indeed a delicate subject, and the writers approach it with great trepidation. In what follows it is not intended to bring accusations against the whole glass industry, but simply to point out conditions that can and should be remedied in many plants. The writers' view is no more than an expression of what eminent men in ceramics and in the glass industry have come to believe, and indeed what some glass plants have already put into practice. Whatever was true of the past, the future will un-

doubtedly bring a new era in glassmaking, characterized by an appreciation of the physics and physical chemistry as well as the chemistry of glass melting, a realization of the value of hiring physical chemists and ceramists to supplement the chemist, of placing furnace regulation and pot arch firing in the hands of trained men rather than of the manager, and of buying high-grade recording pyrometers which afford a permanent record of the utmost value.

Pot Arch Design.—The usual arch is exceedingly crude in design, and its defects are so apparent that it is unnecessary to dwell on them at length. The firebox is at the rear, and the flame, whether from coal, gas or oil fuel, rises and curves over a bridge wall, spreads through the arch proper and passes out through an opening in the floor under the pot, or through flues in the side walls. The back of the pot is nearest the bridge wall and is the hottest portion of the pot, while the hood is nearest the door and is consequently the coolest part. Actual tests with thermocouples have shown a difference in temperature of 200–300 degrees Fahr., even at low temperatures between a point over the back of the pot and a point near the bottom of the door. Furthermore it is impossible to carry the heating beyond 2000 or 2100 degrees Fahr., especially where natural gas or coal is used. With oil, the firebox would melt down if the bottom of the pot were raised to 2500 degrees, because of the enormous difference (500 to 600 degrees) between the temperature of arch and firebox. There is great loss of heat through the walls and crown, which are never insulated, and most of all up the stack. Cold air is sucked in through cracks in the door, as may be demonstrated by holding one's hand near the peephole, and the door itself is a good conductor of heat, as is proved by the fact that points inside are lower in temperature than elsewhere in the arch.

To improve these conditions, several courses might be suggested. Walls and crown should be covered with an efficient insulator such as cork brick or silocel, and the door should be in one solid piece, sliding vertically or horizontally and should be heavily insulated. As to firebox location it would be better to have a firebox on each side and do away with the rear firebox, as

this would prevent the direct impingement of the flame upon the back of the pot. Twin arches should be done away with and each should be separate and have its own stack. Needless to mention, each arch should be equipped with couples, connecting with a pyrometer, and some study given to the printed record of every heat.

It is high time that we got away from the ancient idea that any old oven will do for a pot arch. Proper design of the arch is an important point in glass production, and has a decided bearing on the operating efficiency of the furnace, for if a pot is damaged in the preliminary heating, it surely will not last long in the furnace, and when replacements become frequent there is, in addition to the expense of the pot and the labor of setting, a decrease in production due to time lost, and also a falling off in quality of the finished ware. Although the pot in the dried state represents a single piece of clay, as nearly homogeneous as skilled workmen can make it, it is, on account of its fineness of grain, very sensitive to sudden heating and cooling, or to uneven distribution of heat. In this respect "flux grade" tank blocks are in the same class with pots, since both materials must possess a finer grain than "refractory grade" blocks in order to reach the required density at working furnace temperatures.

Heating Schedules.—The average glass manufacturer has hitherto been somewhat careless in his treatment of pots in the arch. Without thermocouples or other instrument to guide him, the furnaceman was expected to bring the pot up gradually to a bright red heat, and the trained eye of the foreman was relied upon in the end to decide when the pot was just right for setting. Where conditions were apparently most favorable, *i. e.*, where natural gas was the fuel used, a common expedient (and, really the only one possible under the circumstances) was to "crack" the valve a trifle at intervals of about 12 hours at the start, and more frequently later on. By actual test, the writers discovered that in one case the temperature jumped upward at a rate of at least 100 degrees Fahr. per hour immediately after the valve was opened, then settled down towards a constant value which persisted for about 10 hours, when the valve was "cracked" again

and the same performance repeated. After reaching a visible red heat the pot was sometimes held at this temperature for days, if it was not needed to replace a broken pot; otherwise it was heated rapidly in order to set it at an early moment. In other plants coal was used as fuel in the arches, and most of us need not be told how difficult it is to maintain a gradually rising temperature with solid fuel.

Now, happily, conditions are changing rapidly for the better, and the writers sincerely trust that in the future such practices as described above will be considered "beyond the pale." Progressive manufacturers are installing thermocouples in their pot arches, with an indicator for the furnaceman and a recorder in the manager's office, and are studying the charts of successive heats, with an honest effort to determine the type of time—temperature curve best suited to their particular conditions. The senior writer, having had years of experience in actual operation of glass furnaces, may be pardoned for suggesting a heating schedule which in his opinion represents a safe guide in this most difficult operation. The schedule follows:

Interval Deg. F.	Rate Deg. per hr.	Time Hrs,
80– 400	8	40
400– 900	12	41
900–1500	10	60
1500–2200	20	35
	Total time,	7+ days

While pots have often been heated in 3 days or less, with apparently good results, evidence based on pot reports covering a period of several years shows beyond a doubt that best results are obtained by taking seven days or more for preheating. Now it is well known that glasshouses have "streaks" of bad luck, or periods during which the pots leak after a few melts, or even after glazing. Though there are probably other contributing factors, the writers wish to put forward two explanations of this phenomenon: (1) when pots fail prematurely, the demand on the arches is increased, and the preheating is therefore accelerated in order to meet the demand, (2) limited arch capacity prevents time being taken to cool the arch to 80 degrees Fahr., hence the initial strain

of heating is intensified. Pot records show that in these periods of bad luck the breakage is not confined to pots made by any one potmaker, but all suffer alike; and it is difficult to explain the wide variety of service given by pots made in the same room, or in the same set, if the blame be laid solely on the potmaker, or on chance variation in the clay.

Need of Reaching Higher Temperatures in the Arch.—It will be noted that in the above schedule the last stage extends from 1500 to 2200 degrees Fahr. While it is a fact that it is impossible at present to attain higher temperatures, due to faulty construction of the arch, and, indeed, many pots are set at a temperature below rather than above 2200 degrees Fahr., we nevertheless maintain that an increase of 200 or 300 degrees would greatly lengthen the average life of pots, by producing in the preheating stage those changes in shrinkage and porosity which are ordinarily left to the furnace itself to bring about. Now it is a fact that American bond clays, especially ball clays, experience a serious alteration in volume and porosity in the temperature interval cone 1 to cone 12, which corresponds approximately to the range between the highest temperature of the arch and melting furnace temperature; hence it is clear that in order to produce these changes gradually it will be necessary to reach the latter temperature (*i. e.*, 2400 degrees or more) in the arch itself.

One of the writers once had an experience with a pot which was heated very carefully in the arch, 7 to 8 days being consumed in the operation, but the final temperature before setting was 1960 degrees Fahr., and this pot after 12 melts (30 days) failed from a crack in the bottom This is not surprising when one considers the great contraction induced in the clay by suddenly plunging it into a furnace at 2300–2350 degrees Fahr.

The English practice of leaving a pot empty in the furnace for 3 days in the hope of thoroughly burning the bottom will not appeal to the American glass manufacturer, for obvious reasons, and we do not see how such an expedient could obviate the danger mentioned above. Evidence from reliable sources shows that in nearly every case where pots are heated up in the furnace, not

in the arch—as is true of new furnaces or newly repaired furnaces —the life of the pots is doubled. This is presumed to be due to continuity of heat treatment together with a slow rate of heating. Bleininger[7] has shown that pots of the porcelain type require heating above 2500 degrees in order to be serviceable, and in commercial usage it is known that such pots are carried to a very elevated temperature in the arch by means of oil-burners.

Pre-heating the Glass Batch.—The vertical cracks which often appear on the inner surface of the walls of a pot, near the melting line, are usually referred to as "batch cracks," the idea being that they are caused by the strains set up in filling and melting the glass batch. Certainly it must be a great shock to the pot to receive a load of 3000 pounds of cold (and sometimes damp) batch, especially when this quantity is shoveled in at one operation, and the room inside is so limited that when melting begins a stream of glass forces out the stopper and the plug in the proof-hole. The question has been raised whether the glass manufacturer might not with profit preheat his glass batch to, say 700 degrees Fahr., thereby lessening this great initial strain on the pot. This might be accomplished with specially constructed batch wagons equipped with screw conveyors, or by some other mechanical device. The reason for supposing that this would to some degree be beneficial lies in the fact that pots which are kept filled with ladled glass (reference is to the "working pots" used with automatic bulb-blowing machines), and are therefore maintained steadily at a constant temperature, often last anywhere from a year to two years or more.

Need of Care in Crushing Batch Materials and in Mixing the Batch.—Most glasshouses in recent years have installed jaw crushers or similar devices for reducing their cullet, and a few are up-to-date in the matter of mixing machinery, but it has not been a great while since such matters were passed over as unworthy of serious attention. In spite of all precautions it is still possible to go into the most modern glass plants and pick large chunks of cullet out of the batch wagons. Though the alkalis are usually in a finely-divided state, the writers know of at least one large plant where it was quite common to see the soda ash in lumps. It is

not the writers' intention to dwell on the importance of thoroughly pulverizing and intimately blending the batch constituents, as everyone nowadays realizes that both the time of melting and the temperature required directly on the degree of contact of the materials. When these matters are neglected, not only is it more difficult to produce first-quality ware, but in addition the length of life of the pots is greatly reduced by corrosion. When one inspects pots which have been recently removed from the furnace, it is noticed that where there is evidence of corrosion, it is always more marked towards the back of the pot. Since the heat is most intense at the back, melting starts in that region first, hence if the alkalis are not thoroughly assimilated they will attack the pot wall and flux the clay. Occasionally there is evidence of marked corrosion of the crown. It has been customary to assume that this is caused by volatile impurities in the potash or soda (*i. e.*, alkali chlorides or sulfates) which sublime and attack the clay in much the same way that a salt glaze is produced on sewer pipe. It was also inferred that this fluxed clay might drip down into the glass and cause stones. A recent example of this action, which looked like a honeycombed crust on the inner surface of the crown, was submitted to a chemical analysis, with the result that no chlorides or sulfates were found, but merely aluminium silicate with small amounts of potash and iron oxide. In the absence of volatile elements, it is possible that this action was due to the fluxing of the crown by lumps of alkali lying on top after the batch was shoveled into the pot. As previously explained, pots are filled often so completely with batch that it forces out the stopper when melting begins.

Relation of Furnace Temperature to Pot Failure.—Glass manufacturers often remark, in criticism of present-day pots, that in the old days when German clay was in use, there was little trouble due to pots bulging in the side. It is true that pots often fail by bulging or "squatting" in the furnace, but the real explanation is quite apart from the presence or absence of German clay. Anyone who has a slight knowledge of modern ceramics will ridicule the suggestion that a relatively fusible clay like the Grossalmerode[8] could possibly heighten the

refractoriness of an American pot batch. The true cause lies in certain conditions attributable to the war and its natural after-effects. In the writers' opinion there are three factors at work: (1) replacement of German potash and possibly other constituents of the batch by materials which make melting more difficult (*i. e.*, increase the melting period or temperature); (2) the great demand for glassware which necessitates working many plants on 24-hour schedules, and the consequent tendency to shorten the time required for melting operations so as to increase production; (3) the present tendency towards glasses difficult to work such as "Pyrex," that is, glasses melted at temperatures near 3000 degrees with a minimum of fluxes. All of these factors, or certainly the last two, should be blamed for the softening or bulging of pots in the furnace.

Manufacturers of heat-resisting glasses realize that it is not practical to melt such glass on a commercial scale in pots, and have therefore, as far as possible, resorted to tanks. Very small tanks ("day" tanks) are being used successfully, as they can easily be maintained at 2800 degrees or more during the melting period and the glass is quickly worked out, while there is no softening of the walls as is the case with pots. However, corrosion is evident at the flux line at an early stage, and it is probable that it is going to be a difficult matter to find fire-clay blocks which will stand up under such service. Pots which have given two melts of "high-pressure" (gauge-tubing) glass often bulge out in the sides so that the clay cracks open and the inner surface of the bottom resembles a plowed field. As regards tanks, it might be well to point out that no commercial "flux" blocks are ever burned at a higher temperature than that corresponding to cone 12, hence it is quite evident that blocks intended for use against heat-resisting glass will have to be burned to a much higher temperature in the kiln, if rapid corrosion is to be avoided. The other alternative is to seek a material much more refractory in nature than fire-clay, and this course will probably be more productive of results in the end.

What may be regarded as an indirect result of the present demands for heat-resisting glass is the idea which has already been advanced by pot manufacturers and glass manufacturers of

differentiating pots according to the use to which they will be put, and of making and selling a certain grade of pot for use with specified kinds of glass. This will be of immense benefit, for hitherto pots have been sold regardless of the character of glass to be made in them, and therefore it has been necessary for pots to give good service under varying conditions. For instance, it is known that lead glass causes marked corrosion of the bottom of the pot, whereas lime glass confines its damage more to the ring and the walls near the melting line. Density of the glass figures prominently in this action, as was shown very cleverly by Rosenhain.[9] Moreover, it has been customary in the past to use burnt flint clay in pots intended for lime glass, but this could not be used in lead glass pots because of the danger of throwing stones. It is to be hoped that this idea of classifying pots and of selling a pot for use with a particular kind of glass will merit the attention from the industry that it deserves.

Conclusion.—In concluding these remarks, the writers wish to emphasize the point that the technical treatment of pots in the glass plant should be entrusted to specially trained men. The furnaceman for obvious reasons should not have this responsibility, and the foreman and the manager, while they have a deeper appreciation of technical matters, are very busy with other questions pertaining to production. Neither should the burden be placed on the chemist, who has all he can do to see to the purity of raw materials and to adjust the glass for color, etc. This duty may safely be entrusted to a young man who has been adequately trained in ceramics and physical chemistry. When more glass manufacturers see the justice of this statement, and employ such men in their plants, real teamwork between the pot factory and the glass factory will be possible, and certain troubles which have afflicted the industry for years will to a great extent disappear.

THE BUCKEYE CLAY POT CO.
TOLEDO, OHIO

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NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

THE "WHY" OF AGEING CLAY[1]

By H. Spurrier

ABSTRACT

Ageing of clay.—(1) *Evolution of* CO_2 was found to continue for over 34 days after pugging and, like the change of plasticity, to proceed more rapidly between 80° and 90° F than below 60°. (2) *Effect of replacing water by non-aqueous liquids* was to inhibit the development of plasticity altogether. (3) *Effect of a dilute solution of* H_2O_2 was to produce a pronounced increase of viscosity and also to stimulate the growth of filaments algae and the consequent evolution of both CO and CO_2. It seems probable, therefore, that the change of plasticity of clays with time is due, in some way, to the growth of such algae. (4) *This algae theory* would explain all the effects found.

New chemical measure of the plasticity of clays.—The ratio of the amounts of Al_2O_3 and SiO_2 dissolved by caustic potash was found, for the three clays tested (Cooley Ball, Edgar Plastic Kaolin and Harris Spruce Pine), to decrease rapidly with diminishing plasticity and therefore might well be used as a quantitative measure of plasticity.

In 1918 a method[2] was developed for the determination of air in pugged clays, by means of which the occluded gases were liberated in a form which made further handling a very easy matter. It seemed desirable to determine the composition of such gases and while it was anticipated that some deviation from a true air composition might occur, it was hardly foreseen that both carbon dioxide and carbon monoxide would be found.

The following composition was, however, found for gases recovered from clay that had been pugged but twenty-four hours previously:

	Per cent
Carbon dioxide	3.85
Oxygen	13.46
Carbon monoxide	1.92
Nitrogen	80.77
Total	100.00

[1] Received Nov. 12, 1920.

[2] Spurrier, This Journal, 1, 710 (1918).

In the note announcing this composition it was remarked: "It is obvious of course that these chemical changes are intimately connected with the well-known physical changes that take place during the ageing and weathering of clays. Some light might in this way be thrown upon the much studied and as yet imperfectly understood question of plasticity." Experiments designed to throw further light on this phenomenon were undertaken, and while in no way complete, some facts have been developed which seem of sufficient interest and possible utility to warrant publication.

In the ageing of clay bodies it was found that plasticity increases at temperatures of 80°–90°F faster than at a temperature of 60°F. Since it was known that the oxygen occluded as air in clays was speedily converted to carbon dioxide and carbon monoxide, it became interesting to know positively whether clay bodies gave off carbon dioxide under ageing conditions. Accordingly a five-pint bottle was cut off close to the bottom and the edge ground smooth. The bottle was inverted and through the two-hole stopper were passed the two ends of a small glass coil in such a manner that the coil was in the shoulder of the bottle. Enough water to immerse the coil was placed in the bottle. A Chromel gauge screen was fitted above the water and upon this were placed the freshly pugged clay blanks and above this was placed a small beaker containing barium hydroxide solution. A glass cover completed the set up.

Almost immediately the barium hydriate showed the presence of carbon dioxide. Each morning the vessel was blown out with fresh air and the barium hydrate solution was renewed. This was continued for 34 days and even on the 34th day carbon dioxide was still coming off in such quantity that a thick scum formed promptly on the surface of the liquid. During this experiment, it was noted that carbon dioxide was evolved more rapidly between 80° and 90°F than when the water circulating in the coil was kept below 60°F. As previously noted, plasticity increases most rapidly between these temperatures. The conditions of the experiment insured a saturated atmosphere during the whole period.

As is well known, there is a close relation between the plasticity

of a clay and the viscosity of slip made therefrom; for instance, if two slips be made from the same clay the one flocculated and the other deflocculated, the viscosity of the flocculated slip will be the greater. In this way relative plasticity may be established in terms of viscosity. Testing in this way, the clay used in the above experiment was found to have much greater plasticity at the end than at the beginning of the experiment.

Following out another line of inquiry, Edgar Plastic Kaolin in separate portions was mixed in a mortar with carbon disulfide, benzene, carbon tetrachloride, ethyl alcohol, ether, bromoform, and sulphuric acid. In no case was the slightest plasticity developed. The mixtures in all cases were granular. Even in the case of sulphuric acid no plasticity was developed until a considerable quantity of water had been added, which was done in very small increments, the mixture being carefully mixed and examined after each addition. From the above the opinion was arrived at that hydroxide ion must be present in order to develop plasticity.

In order to throw some further light on this question, it was decided to try the effect, on a slip, of the addition of 3 per cent hydrogen peroxide. Accordingly two 100 cc Nessler tubes were charged with 100 cc each of a carefully mixed slip. To one, 5 cc of 3 per cent hydrogen peroxide were added and the covered tubes set aside for twenty-four hours. At the end of this time, there was a pronounced increase in viscosity of the slip to which the hydrogen peroxide had been added and no change in the other, as shown by the viscosimeter. The two slips were kept in order to see if any further change would take place. In about a week tiny green specks were noted in the tube that had received the addition of hydrogen peroxide, but very careful inspection with a X-10 lens failed to reveal any such specks in the untreated tube.

One of these specks was removed, examined microscopically and found to be a green alga. On keeping, the tube failed to show much increase in algae and it was thought that, owing to exhaustion of the dissolved oxygen further growth had been arrested. Accordingly, a further addition of 5 cc of hydrogen peroxide was made—with the gratifying result of an almost imme-

diate growth. As the growth seemed to slow down, further additions of hydrogen peroxide were made with consistent increase of filamentous algae. During this growth, the slip became much more viscous, so much so that the volume had to be increased beyond the original 100 cc.

Another change of much interest occurred, namely, the evolution of considerable quantities of gas, which it seemed obvious was the result of vegetal respiration. On closing the tube with a rubber stopper provided with an educt tube, it became possible to collect enough of the gas to test for carbon monoxide and carbon dioxide, both tests resulting positively. Under the circumstances, the presence of the two oxides of carbon might have been confidently postulated, as it is well known that both these gases result from algal metabolism. Mr. Seth Langdon[1] showed that carbon monoxide was produced by the giant Kelps of the Pacific Coast "Nereocystis luelkeana" as a product of respiration, that it is produced in light or dark and only on the surface or floater portion, and that the presence of oxygen is essential to its production. These findings agree well with the above, that the exhaustion of the oxygen in the slip, arrested growth and the addition of oxygen in the form of peroxide of hydrogen, stimulated such growth as it is equivalent to exposing it to moist air. As is well known, algae require air and therefore usually occur upon moist surfaces, but can not thrive when entirely submerged in liquid on account of lack of oxygen.

The cause of the improvement in the plasticity of clay piles that are exposed to damp weather and frequently turned over to expose fresh surfaces, now becomes evident—it promotes algal growth which in some way increases plasticity. There are probably several contributory causes which singly or together produce the complex phenomenon which we term "plasticity" and it might be quite correct to assume that there is more than one kind of plasticity. While some light has been thrown upon this interesting question, one is naturally led to inquire just why algal growth increases the plasticity of clays. This question can only be answered by further investigation which it is intended to pursue as opportunity offers.

[1] Langdon, *Science*, **49**, 573 (1919).

One somewhat confusing point in the effect of algal growth is the copious formation of carbon dioxide, because the writer has observed that the introduction of free carbon dioxide reduces the plasticity of clays. The question of plasticity of clays was concurrently attacked from another angle which yielded data of profound significance.

It became interesting to investigate the action of an electrolyte upon clays exhibiting wide differences in initial plasticity. The treatment was as follows: A quantity of the clay was weighed out which represented 50 grams of dry clay. The necessary weight was calculated from a moisture determination on a separate portion, as it was prejudicial to dry the portion to be experimented on. The weighed portion was made into a slip with 250 cc of water and 83 cc of a solution of 30 grams of caustic potash in 250 cc of water were added. The warm mixture was stirred thoroughly, 500 cc more water were added, and the mixture was thoroughly stirred and allowed to settle. From the clear supernatant liquid, a portion was drawn off, acidified with hydrochloric acid, and the silica and alumina determined in this with great care. The results are expressed as a ratio of silica to alumina, silica being taken as unity in all cases.

The three clays selected were, in the order of decreasing plasticity, Cooley Ball, Edgar Plastic Kaolin, and Harris Spruce pine. It will be noted that the ratio of alumina to silica dissolved by the potash decreases as the plasticity diminishes.

	Dissolved SiO_2	Dissolved Al_2O_3
Cooley Ball	1	2.17
Edgar Kaolin	1	1.009
Harris Spruce Pine	1	0.35

Analyses of the Edgar Kaolin and the Spruce Pine showed the following figures:

	Edgar kaolin	Harris spruce pine
Silica	46.49	46.30
Alumina	38.85	38.57

Theoretical Kaolinite gives Silica, 46.6; Alumina, 39.49; $SiO_2 : Al_2O_3$ as 1 : 0.847.

The residues from the above experiments were washed until free from alkali and examined. The Harris clay residue lacked

all semblance of plasticity and was not sticky. The Edgar Kaolin residue was slightly plastic and more sticky than originally. The Cooley Ball clay residue was somewhat plastic and showed extraordinary stickiness.

It would seem that the determination of the ratio of alkali soluble silica to alkali soluble alumina, throws so much light on the character of a clay as to at once distinguish, by chemical data, differences between clays that ordinary determinations of silica and alumina would entirely fail to indicate.

The practical potter of experience distinguishes readily between sticky and plastic clays by the "feel." The above procedure also does this and the results can fortunately be expressed in figures.

The writer is fully conscious that the above data are hardly sufficient and need the confirmation and elaboration of further experiment, but he expresses the hope that the above will suffice to stimulate others to further activity in this direction.

Detroit, Michigan

THE USE OF PLASTIC CLAY GROG IN PREVENTING SPALLING[1]

By Raymond M. Howe and Stewart M. Phelps

ABSTRACT

Effect of calcined clay grog on the properties of fire-brick.—A medium dense-burning clay was calcined at cone 8, then ground and mixed with plastic clay in various proportions up to 40 per cent. An air spalling test of the burned bricks showed that the grog increased the *resistance to spalling* about 5 per cent for each per cent of grog added. The results for *other physical properties* agreed with those found by previous observers; the bricks with grog were more porous and weaker mechanically but showed less drying and burning shrinkage.

1. Introduction

When fire-brick become partially vitrified their resistance to temperature change is lessened and sections spall off.[2] Coarse grinding, soft burning, and a uniform open structure favor high resistance to spalling; where two or more clays are available, the use of a large proportion of open burning clay is desirable. In certain localities, however, it is impossible to change the grind, firing procedure, or process of manufacture applied to the single available plastic clay. Consequently it was decided to calcine a portion of raw clay and to introduce the resulting grog as a part of the batch. This method of overcoming spalling is by no means original but at the same time no quantitative data are available which concern the direct application of plastic clay grog in reducing or overcoming spalling.

2. Results of Previous Investigations

Geijsbeck[3] has stated that the drying and burning properties of ceramic bodies could be improved by the addition of grog, and that the quantity of, rather than the size of, the grog is the

[1] Received May 24, 1920.

[2] R. M. Howe, *J. Am. Ceram. Soc.*, 3, (1920).

[3] S. Geijsbeck, "Note on the Action of Grog in Ceramic Bodies," *Trans. Am. Ceram. Soc.*, 1, 133 (1905).

controlling factor. The first ten per cent produces the most noticeable change in the properties of the mix.

Rigg[1] concluded that the use of grog was desirable, for its incorporation into the batch results in the general improvement of the finished product. He did not advise the use of coarse or fine grog but advocated using a mixture of fine and medium sized particles.

Fulton and Montgomery[2] found that the water of plasticity, the drying shrinkage, the burning shrinkage and the strength of the green ware decreases with increasing amounts of grog, when from 0 to 75 per cent is used. The strength of the burned pieces decreases, and the porosity increases with the addition of grog until over-burning begins. Fine grog is associated with greater drying and burning shrinkage than coarse grog, and the resulting product is stronger.

Kirkpatrick[3] confirmed Rigg's results and concluded that the strength of fire-clay bodies depended upon the size of the grog; it should not be too coarse or too fine, but should be present in several sizes.

The preceding citations give valuable information but do not apply directly to spalling. Windzus,[4] however, investigated the subject and stated that spalling may be reduced by increasing the size of grog, or by reducing the plastic content of the batch. These conclusions, reasonable though they are, were not warranted by his few simple experiments.

When the preceding statements are summarized, they apparently justify the following conclusions:

When grog is added to plastic fire-clay the resulting mixture is more porous; it possesses superior drying and burning properties, but is weaker before and after burning. The size and quan-

[1] Gilbert Rigg, "The Application of Grog in Fire-brick Manufacture," *Met. Chem. Eng.*, 8, 523 (1910).

[2] C. E. Fulton and R. J. Montgomery, "Effect of Grog in a Fire-clay Body," *Trans. Am. Ceram. Soc.*, 17, 409 (1915).

[3] F. A. Kirkpatrick, "Effect of Sizes of Grog in Fire-clay Bodies," *Trans. Am. Ceram. Soc.*, 19, 268 (1917).

[4] P. Windzus, "Resistance of Refractory Ware to Abrupt Changes in Temperature," *Tonind. Ztg.*, 36, 1205 (1912); *Met. Chem. Eng.*, 10, 662 (1912).

tity of the grog control the physical properties of the mixture and of the burned product.

3. Present Investigation

A. Materials.—A medium dense burning plastic clay fusing at cone 30 was taken as the basis of the experiments herein described. A large amount of this clay was calcined at cone 8 and after being crushed to the necessary degree of fineness, it was used as grog.[1] The analysis of the grog is as follows:

Silica	63.86
Alumina	30.13
Ferric oxide	3.79
Calcium oxide	.76
Magnesium oxide	.44
Alkalies	.86
Total	99.84

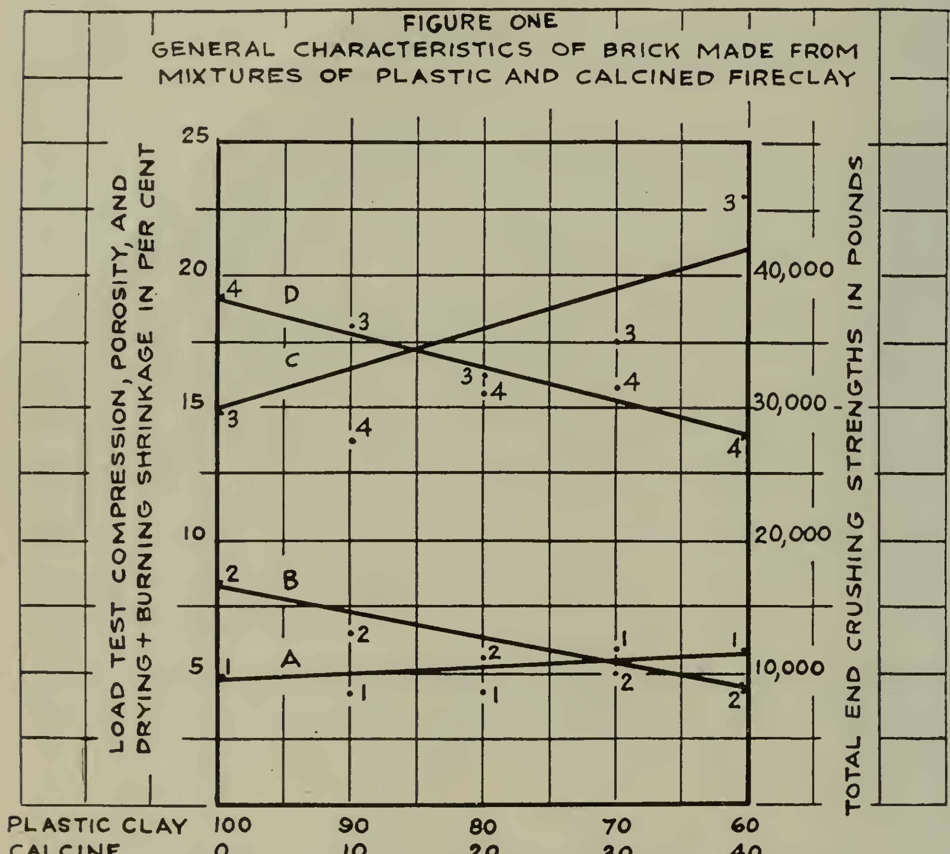
B. Preparation of Samples.—Commercial sized batches were made which had the following compositions:

Number	Plastic clay Per cent	Grog Per cent
B- 0	100	0
B-10	90	10
B-20	80	20
B-30	70	30
B-40	60	40

These mixtures were tempered in a pug mill, shaped in an auger machine, dried, and burned to cone 8.

C. Results of Physical Tests.—Representative samples of each of the five mixes were subjected to those tests which indicate the physical properties of fire-brick or which measure their relative resistance to spalling. The standard methods of the American Society for Testing Materials or of the American Ceramic Society were used for those tests which have been standardized. The results of the general tests are plotted in figure 1. The

[1] The term "grog" appears to have several meanings in the different ceramic industries, for it applies to raw flint clay, calcined flint clay, ground bats, ground biscuit ware, etc. Generally, however, the term refers to material of low plasticity and shrinkage and in that sense applies to this case.



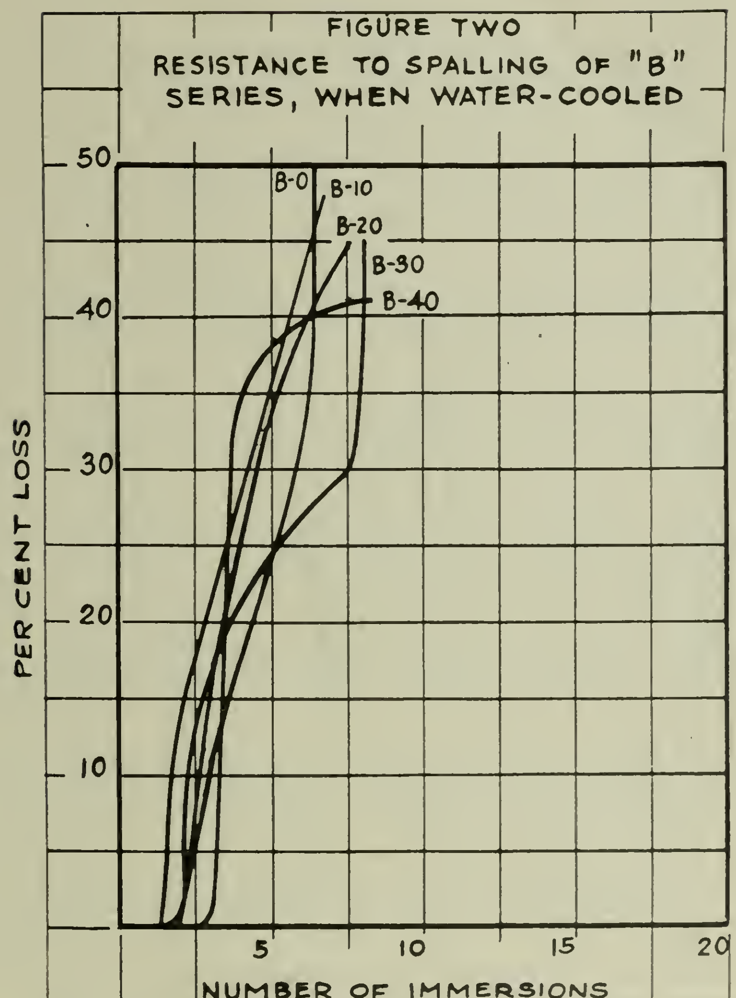
CURVE A (POINTS 1) COMPRESSION IN LOAD TEST
CURVE B (POINTS 2) TOTAL DRYING AND BURNING SHRINKAGE
CURVE C (POINTS 3) POROSITY
CURVE D (POINTS 4) CRUSHING STRENGTH

results of the water spalling tests are given in figure 2, and the air spalling data are presented in figure 3.

4. Discussion of Results

It is evident that the addition of grog to plastic clay results in the formation of a more porous product of the same fusion point when the batch is shaped by the stiff mud process.

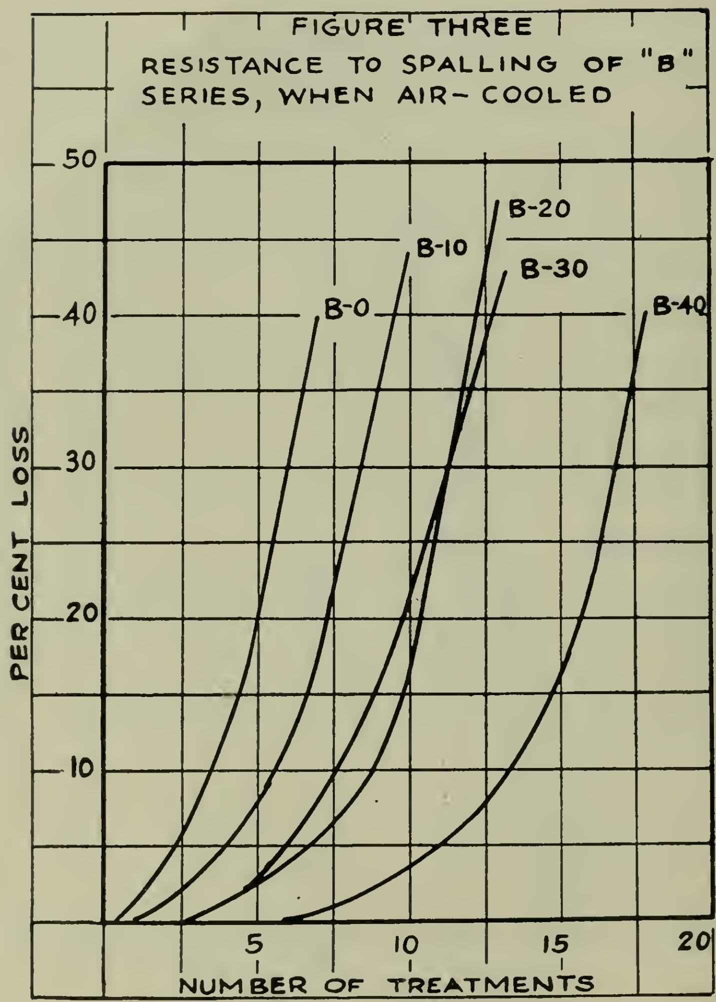
The grogged specimens were weaker mechanically and compressed slightly more in the load test, because of their more open structure. The total drying and burning shrinkage variety inversely with the grog content of the fire-brick, although it is quite probable that the size of the grog is also a controlling factor.



These observations are in accordance with those which have been made by other investigators where laboratory test pieces have been studied.

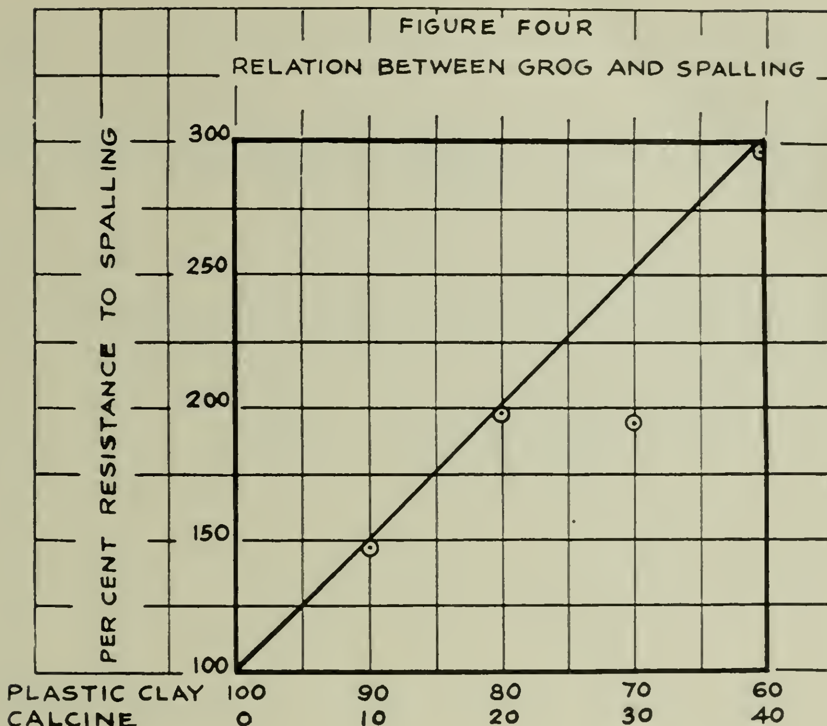
When samples were subjected to the water spalling test it was evident that the treatment was too severe for this type of firebrick. When the results were plotted there was a slight indication of a difference in structure, although this difference was too slight to permit the drawing of definite conclusions. Consequently samples were air-spalled and results of a more comparable nature obtained. When these latter observations were plotted the effect of grog upon brick structure was shown to be pronounced and very definite conclusions could be deduced.

It is appreciated that the air-cooling test is too slow for certain



types of fire-brick, but it is also evident that the water-cooling test is too rapid for fire-brick of the type under consideration. There are millions of fire-brick made yearly which shatter after a few immersions in water, yet they give satisfactory service in blast furnace linings, stove checkers, soaking pits, and in side-walls. Figures 2 and 3 show that it is impossible to obtain a distinction between fire-brick of this type with the water spalling test, while a distinction can be obtained by cooling in air. The writers believe that a rough classification can be obtained by means of the water spalling test, but if the specimens fail rapidly more tangible results obtain when they are cooled in air.

Figure 3 shows very clearly the way in which the addition of grog effects the resistance of the product to spalling, but it



was deemed advisable to plot the same data in another manner. Consequently, the abscissae of each curve as its intersection with the 10, 20, 30 and 40 per cent loss axis were averaged. B-0 (the original mixture) was assigned a value of 100 per cent and when the various abscissae were compared it was possible to compute the resistance to spalling of each mixture in terms of B-0.

Batch.	B-0	B-10	B-20	B-30	B-40
Abscissa at 10 per cent loss axis....	3.5	5.5	9.0	7.5	13.3
Abscissa at 20 per cent loss axis....	5.0	8.3	10.3	9.8	15.8
Abscissa at 30 per cent loss axis....	6.0	8.5	11.2	11.2	17.0
Abscissa at 40 per cent loss axis....	7.0	9.5	12.3	12.8	18.0
Average..........................	5.4	7.9	10.7	41.3	16.0
Per cent Resistance to Spalling.....	100	147.6	198.7	191.6	295.9

When these calculations were made it became obvious that the addition of one per cent of grog increased the resistance of these mixtures about five per cent with respect to resistance to spalling. The samples B-10, B-20 and B-40 conform to this rule very closely, although B-30 for some unknown reason does not. It appears justifiable to state, however, that the addition of grog

up to 40 per cent, increases the resistance of the brick structure to spalling about five per cent for each per cent of grog added, under the conditions of the investigation. However, this statement does *not* warrant the conclusion that all grogged bodies are more resistant to spalling than all of those free from grog. It should be more closely limited to the statement that *the calcining of a portion of this particular clay increased the resistance of the product to spalling to a remarkable degree.* Such a statement undoubtedly applies to any one particular plastic clay.

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Mellon Institute of Industrial Research
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EXPERIMENTS IN DEAD-BURNING DOLOMITE AND MAGNESITE[1]

By H. G. Schurecht

ABSTRACT

Stability of calcined dolomite; effect of fineness of raw material, nature of flux and temperature of burning.—Dolomite is difficult to dead-burn because the absorption of moisture from the air produces a gradual slacking due, probably, to the hydration of lime and various lime compounds, and this tends to cause disintegration. With all the fluxes tried, 100 mesh raw material gave greater resistance to slacking than 8 mesh size. This resistance decreased, however, with increasing temperature of calcining, by an amount which seems to depend on the silica and alumina content of the flux, being greatest for basic open hearth slag and kaolin, less for flue dust, and iron ore, and least for roll scale. The stability also varied with the proportions of flux used, being greater, as a rule, for smaller proportions.

Shrinkage, porosity and vitrification of calcined dolomite; effect of flux and burning temperature.—The shrinkage and porosity curves for mixtures containing flue dust, iron ore or roll scale are very similar. The higher the proportion of flux, the lower the temperature required to get maximum shrinkage and minimum porosity. Kaolin and basic open hearth slag behaved peculiarly in that vitrification depended more on the burning temperature than on the proportion of flux used.

Experiments in making dolomite brick.—It was found that ageing of the wet calcined material was necessary to prevent cracking of the bricks upon drying. With 5 per cent $MgCl_2$ as binder, comparatively strong brick were obtained. High shrinkage on firing caused excessive cracking, but the bricks were extremely dense and did not disintegrate until after four to six months. Unfired tar-bonded brick were made with sufficient strength to stand shipping and with a storage life of about four months. Fired tar-bonded brick showed less shrinkage and cracking than similar brick made with water. If dipped in tar to protect them from moisture, such brick will last five or six months before disintegration. It is possible, then to make dolomite brick with a storage life long enough to allow shipping and placing in furnaces.

Stability, shrinkage and porosity of calcined magnesite; effect of flux and temperature of burning.—Unlike dolomite, magnesite showed less slacking effect the higher the temperature of burning. Roll scale gave greater stability than iron ore, probably because of its lower silica content. The product was comparatively porous and with low shrinkage, even with high proportions of roll scale.

[1] By permission of the Director, U. S. Bureau of Mines

Introduction

In 1913, 158,519 tons of calcined magnesite[1] were imported into the United States from Austria Hungary. During the war this supply was cut off and American manufacturers were forced to rely chiefly upon California, Washington and Canadian magnesites. Chiefly as a result of this condition production of crude California magnesite increased from 9,632 tons in 1913 to 211,663 tons in 1917, while the importation of Canadian magnesite increased from 494 tons in 1913 to 20,872 tons in 1918.

Canadian magnesite was used largely because of the remoteness of the California and Washington deposits from the middle east steel centers. Dolomite in abundance occurs near the steel centers and an extremely pure material may be obtained at comparatively low cost.

The untreated domestic magnesite is rather pure and not as satisfactory as the Austrian magnesite, known as Breunnerite, which contains sufficient iron carbonate to render it suitable when calcined for the manufacture of refractories. Sufficient flux should be present in magnesite to prevent the calcined material from slaking and to produce a dense product.

Dolomite is comparatively difficult to dead-burn owing to its tendency to disintegrate. This disintegration may be divided into two classes:

(1) Disintegration due to change of state on heating and cooling.

(2) Disintegration due to slacking by taking up moisture from the air.

In the first case the disintegration is comparatively rapid, occurring during the cooling, and is due to the conversion[2] of the beta to the gamma from of calcium orthosilicate, $2CaO.SiO_2$ which starts at 675°C in cooling and continues even after it is taken out of the furnace. The conversion is accomplished by an increase in volume of 10 per cent, which shatters the calcine into fine dust and sometimes breaks off fragments of the sintered dolomite. This action is called "dusting" and is well known

[1] C. G. Yale, and R. W. Stone, "Magnesite in 1918," *U. S. Geol Survey, Mineral Resources of the U. S.* **1919**, 141–158.

[2] G. A. Rankin, "The Ternary System $CaO–Al_2O_3–SiO_2$," *Am. Jour. Sci.*, **39**, 7–8 (1915).

in the manufacture of Portland cement. Bates[1] found in Portland cements high in magnesia that the amount of orthosilicate formed is decidedly increased.

The writer noticed dusting in the cooling of calcined Canadian magnesite which contains a high per cent of lime. The conversion of the orthosilicate in the heating and cooling of Canadian magnesite has caused considerable trouble in the use of this mineral for making brick as the dusting tends to disintegrate the brick.

Disintegration due to taking up moisture from the air is due to the presence of free lime in the calcine, which readily takes up water and forms $Ca(OH)_2$. In the formation of the hydrate the lime increases in volume and finally disintegrates the mass. Disintegration of this type takes place comparatively slow.

Hydraulic compounds may be formed with lime which take up moisture from the air and cause the sintered dolomite to disintegrate. Some of the possible compounds formed in calcined dolomite are the following:

$CaSiO$	$3CaO.Al_2O_3$	$CaO.Fe_2O_3$
$3CaO.2SiO_2$	$5CaO.3Al_2O_3$	$Al_2O_3SiO_3$
$2CaO.SiO_2$	$CaO.Al_2O_3$	$CaO.Al_2O_3.2SiO_2$
$3CaO.SiO_2$	$3CaO.5Al_2O_3$	$2CaO.Al_2O_3.SiO_2$
$CaOMgO.SiO_2$	$2CaO.Fe_2O_3$	$3CaO.Al_2O_3.SiO_2$

Klein[2] found that $2CaO.SiO_2$ (B form) and $3CaO.SiO_2$ and all of the aluminates with the exception of the tricalcium aluminate developed hydraulic properties.

Campbell[3] found that calcium ferrites corresponding to the following empirical formulas showed hydraulic properties and when tested as to their ability to set, showed an initial set in 14 to 22 minutes, and a final set in about $^3/_4$ of an hour, being similar to the calcium aluminates found in Portland cement.

1. $5CaO.3Fe_2O_3$
2. $6CaO.3Fe_2O_3$

[1] P. H. Bates, "Properties of Portland Cement Having a High Magnesia Content," *Bureau of Standards Tech. Papers*, **102**, 40 (1918).

[2] A. A. Klein, and A. J. Phillips, "The Hydration of Portland Cement," *Trans. Am. Ceramic Soc.*, **16**, 313–841 (1914).

[3] E. D. Campbell, "Some Mix-Crystals of Calcium Ferrite and Aluminate," *Jour. Ind. Eng. Chem.*, **11**, 116–120 (1919).

Furthermore Bates[1] found that high magnesia cements show a tendency to disintegrate upon storage, which may be another cause of the disintegration of dolomite brick.

By "dead burning" is meant, the sintering of dolomite with a flux at a high temperature in order to place it in such a state that it will not disintegrate after storing for long periods. It should also be calcined high enough to remove most of the firing shrinkage.

In work previously reported[2] the writer conducted experiments in dead-burning dolomite by the addition of coal tar, flue dust, iron ore, basic open hearth slag, shale, kaolin, roll, scale, and chlorides when added to raw dolomite, and calcined to cone 18. Fluxes high in silica produced calcines which disintegrated on cooling due to dusting. Fluxes low in silica, as roll scale, iron ore and flue dust were more effective in dead-burning than the siliceous fluxes, as shale and blast furnace slag. The best mixtures, however, disintegrated at the end of 130 days when in the form of briquettes $1 \times 1 \times 1$ in., whereas it is desirable to prepare calcined dolomite that will withstand storage for much longer periods.

The former work was done on coarsely ground dolomite (through 8 mesh) and the trials were calcined at cone 18. By grinding dolomite finer, a more intimate mixture is obtained and by calcining to higher temperatures a more thorough sintering takes place. In the following work the dolomite and fluxes were ground to 40 and 100 mesh size and calcined to cones 14, 20 and 26 to determine if finer grinding and higher calcination temperatures would produce a more stable product.

The effects of different fluxes and calcining temperatures on the shrinkage and porosity of dolomite and magnesite were also studied to determine the amounts of fluxes and calcining temperatures necessary to obtain maximum shrinkage.

Various methods for making brick from calcined dolomite were tried, both with hydrous and anhydrous binders.

Description of Work

The effects of fine grinding and different calcination temperatures were first studied.

[1] P. H. Bates, *Loc. cit.*, p. 32.

[2] *Jour. Am. Ceram. Soc.*, **2**, 291–805 (1919).

The following fluxes were added to dolomite ground to 100 mesh size, and similar mixtures were also made with dolomite ground to 40 mesh size:

(1) Flue dust; (2) iron ore; (3) basic open hearth slag; (4) kaolin; (5) roll scale.

The chemical analyses[1] of the fluxes are as follows:

	1	2	3	4	5
Silica (SiO_2)	9.5	7.9	15.9	43.8	4.2
Titanium oxide (TiO_2)	..	0.3	..	....	....
Aluminum oxide (Al_2O_3)	4.6	5.6	7.6	40.2	5.2
Ferric oxide (Fe_2O_3)	72.1	78.2	20.8	0.8	19.6
Ferrous oxide (FeO)	..	...	..	...	71.3
Manganese oxide (MnO)	..	trace	2.3	...	...
Calcium oxide (CaO)	2.5	none	40.6	none	none
Magnesium oxide (MgO)	1.0	0.6	13.0	0.06	0.20
Potassium oxide (K_2O)	0.6	0.04	none	none	0.20
Sodium oxide (Ng_2O)	0.3	0.3	none	none	none
Sulphur trioxide (SO_3)	0.3	none	none	none	none
Carbon dioxide (CO_2)	1.5	none	none	none	none
Hygroscopic water (at 105°C)	0.6	0.5	0.0	1.5	0.0
Loss on ignition	6.8	6.9	..	13.9	...
	99.6	100.1		100.2	100.9

One inch cubes of the various mixtures were molded and calcined to cones 14, 20 and 26 in a Hoskins carbon resistance furnace. Immediately upon being taken from the furnace they were cooled in a desiccator and weighed. After standing in air at room temperature for different periods they were reweighed in order to determine the increase in weight due to taking up moisture and CO_2. The cubes were weighed at the following intervals: 2, 5, 10, 18, 28, 38, 50, 65, 80, 100, 125, 150, 175, 200, 220, 250, 275, 300 and 325 days. The periods at which the briquettes disintegrated and no longer showed mechanical strength were also noted.

Below are given the chemical analyses of the Cedarville dolomite and Canadian magnesite used in the investigation. The analyses[2]

[1] The chemical analyses were furnished by A. G. Fieldner of the U. S. Bureau of Mines, Pittsburgh, Pa.

[2] Analyses were furnished by A. C. Fieldner of the U. S. Bureau of Mines, Pittsburgh, Pa.

of other Ohio dolomites and of calcined Austrian magnesite are given for comparison.

	1	2	3	4	5	6	7
Silica (SiO_2)	0.4	0.6	0.2	0.0	6.7	2.2	0.7
Aluminum oxide (Al_2O_3)	0.5	0.3	0.3	.01	2.5	.6	2.2
Ferric oxide (Fe_2O_3)	.5	.6	.4	.30	1.1	.8	7.2
Ferrous oxide (FeO)	..	..	..	..	..	..	none
Calcium oxide (CaO)	30.2	29.9	30.3	30.20	28.5	11.1	1.8
Magnesium oxide (MgO)	21.8	21.9	21.9	22.0	18.3	39.0	86.1
Potassium oxide (K_2O)	trace	0.2	none	none	0.4	none	none
Sodium oxide (Na_2O)	trace	.04	none	none	.1	none	none
Sulphur trioxide (SO_3)	none	none	none	.1	.1	none	0.2
Carbon dioxide (CO_2)	46.8	46.5	47.5	46.8	41.6	47.1	1.7
Hygroscopic water at 105° C.	0.1	0.1	0.01	0.0	0.2	0.0	0.3

1. Dolomite from Cedarville, O. 2. Dolomite from Springfield, O. 3. Dolomite from Genoa, O. 4. Dolomite from Woodville, O. 5. Dolomite from Hillsboro, O. 6. Magnesite from Canada. 7. Calcined magnesite from Austria.

To determine the effects of different fluxes and calcining temperatures upon the shrinkage and porosity of the dolomite and magnesite mixtures, briquettes ($1 \times \frac{1}{2} \times 2$ inches) were used. Small briquettes were employed in order to minimize cracking, resulting from excessive firing shrinkage, which occurs to a greater degree in briquettes of large size. Five per cent of dextrine was used as a binder in molding the briquettes and the raw volumes were determined in a small pycnometer volumeter. The briquettes were then fired in an electric furnace to cones 14, 17, 20, 23, 26 and 30. After firing the volumes were again determined to obtain the firing shrinkage. The apparent porosities were determined in the customary manner, using kerosene as the liquid. The true specific gravity determinations were made in a pycnometer specific gravity bottle with kerosene as the liquid.

In the experiments in making dolomite brick, the following mixtures, screened through a 100 mesh sieve, were calcined at cone 20, Cedarville dolomite being used.

1. 10 per cent iron oxide, 90 per cent dolomite
2. 15 per cent iron oxide, 85 per cent dolomite
3. 25 per cent iron oxide, 75 per cent dolomite

The following binders were tried:

1. 5 per cent sodium silicate
2. 5 per cent caustic lime
3. 5 per cent magnesium chloride
4. 12 per cent coal tar

Effects of Degree of Fineness of Raw Dolomite and Different Fluxes and Calcination Temperatures on the Stability of Calcined Dolomite and Magnesite

Flue Dust and Dolomite.—Figures 1 and 2 show the effect of different calcining temperatures and fine grinding on the tendency of flue dust-dolomite mixtures to increase in weight upon storage. It is evident that grinding the dolomite to 100 mesh size before calcination decreases its tendency to increase in weight after calcination, when compared to results[1] obtained in dolomite which has been ground to 8 mesh size previous to calcination. For example, 8 mesh dolomite mixtures prepared with 15% flue dust increased in weight 7% at the end of 80 days after calcining at cone 18, whereas with 100 mesh dolomite, the same percentage mixture increased in weight only 0.9% at the end of 80 days after calcining to cones 14 and 20.

Raising the calcining temperatures increases the tendency of the calcine to increase in weight due principally to taking up moisture and CO_2. For example, the mixture prepared with 15% flue dust increased in weight 1.4% at the end of 150 days after calcining to cone 14, 2.9% after calcining to cone 20 and 3.9% after calcining to cone 26.

Figure 2 shows the effects of flue dust when mixed with 40 mesh dolomite and calcined to cone 26. Increasing the per cent flue dust decreases the tendency to increase in weight up to an addition of 10%. With 15% flue dust it has a tendency to increase in weight more than with 10%. Adding 25% again decreases the tendency to increase in weight and 30% again increases the tendency. A somewhat similar relation is obtained with the 100 mesh dolomite mixture (see figure 1) after calcining to cone 14, but when these mixtures are calcined to cones 20 and 26 increasing

[1] *Loc. cit.*, p. 295.

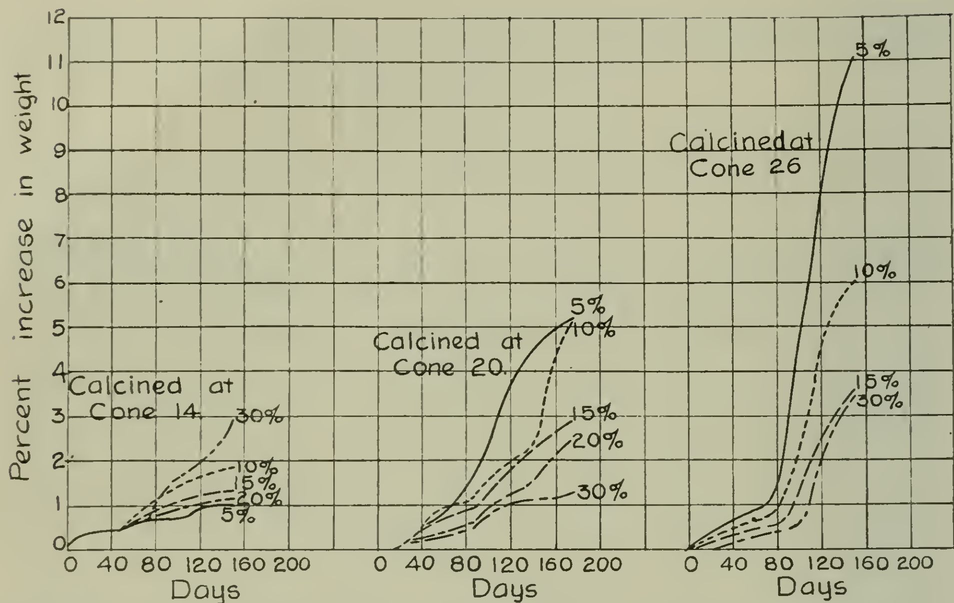

FIG. 1.—The effect of flue dust on the stability of dolomite after calcining at different temperatures. Dolomite and flue dust through 100 mesh.

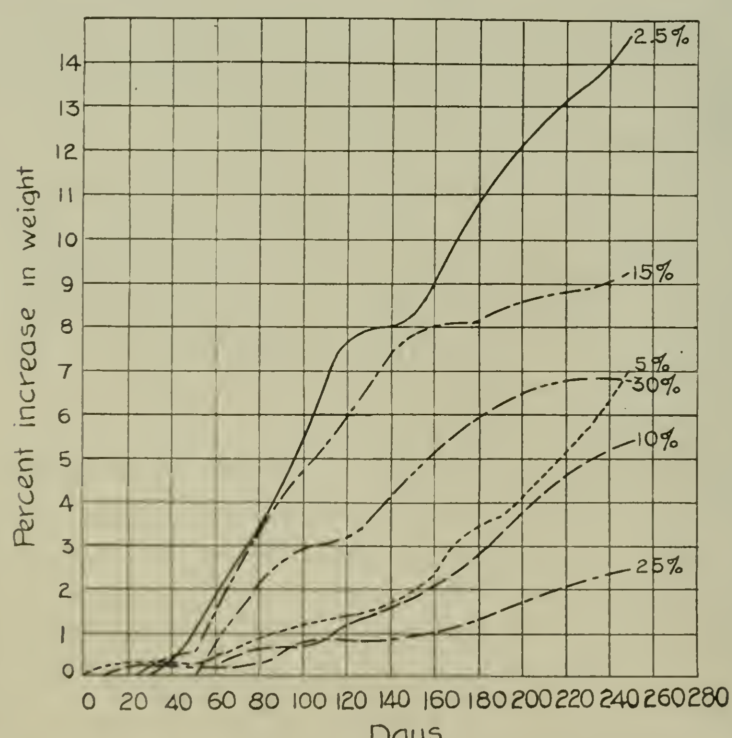

FIG. 2.—The effect of flue dust on the stability of dolomite after burning to cone 26. Dolomite through 40 mesh; flue dust through 20 mesh.

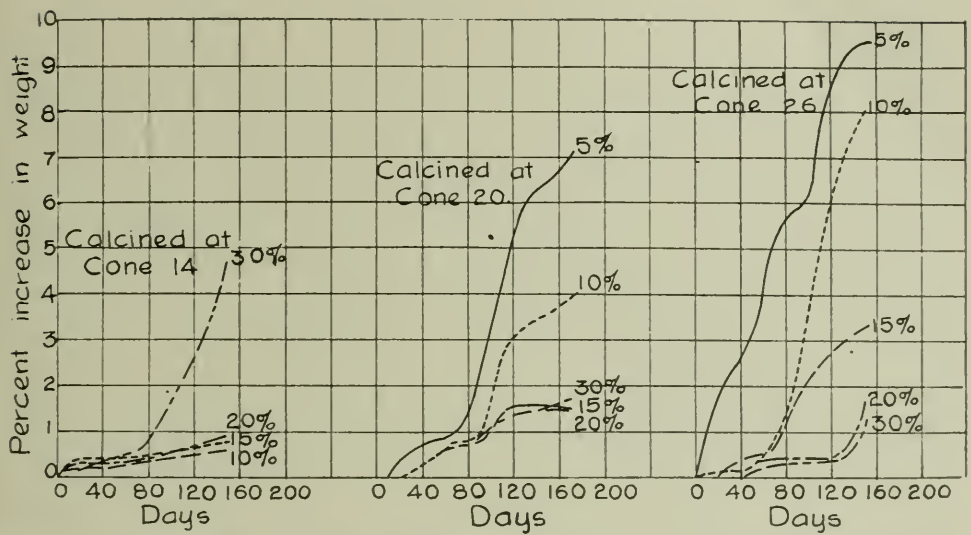

FIG. 3.—The effect of iron ore on the stability of dolomite after calcining at different temperatures. Dolomite and iron ore through 100 mesh.

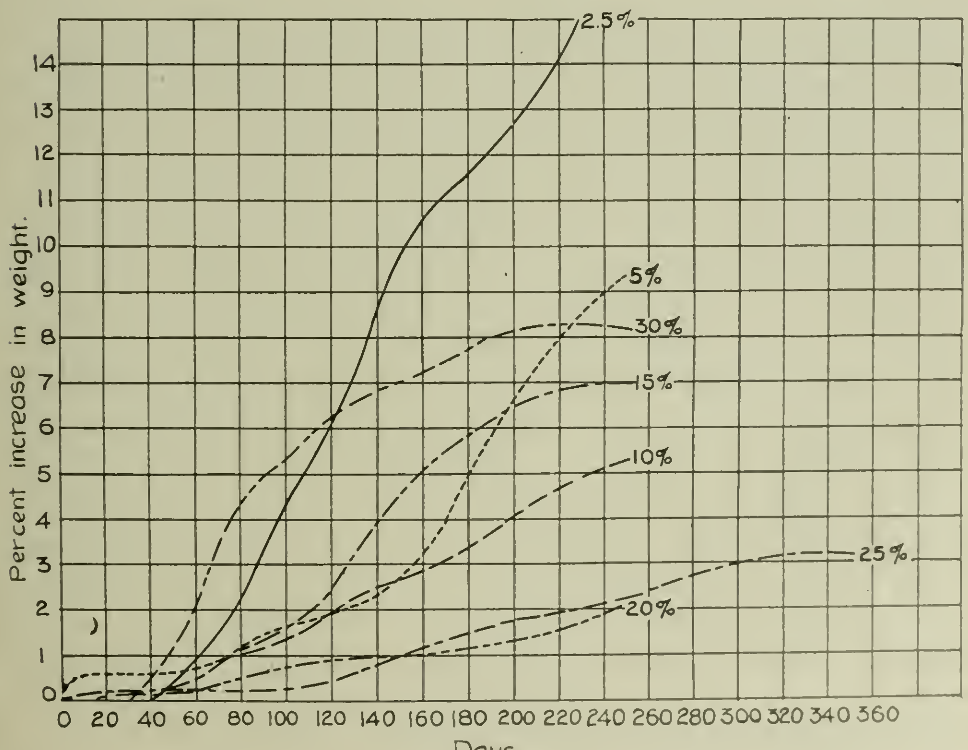

FIG. 4.—The effect of iron ore on the stability of dolomite after burning to cone 26. Dolomite through 40 mesh; iron ore through 20 mesh.

the flue dust content decreases the tendency to increase in weight upon storage.

It is evident that compounds which have a tendency to increase in weight when exposed to air are formed in calcined dolomite. Microscopic studies are now being made to determine the nature of these compounds and have already shown the presence of considerable $2CaO.SiO_2$, which evidently accounts for the disintegration due to dusting. Considerable uncombined iron was found as small globules of metallic iron together with free lime.

Iron Ore and Dolomite.—The results with iron ore and raw dolomite are shown in figures 3 and 4. Fine grinding of the raw dolomite again decreases the tendency to increase in weight during storage. Eight mesh dolomite prepared with 15% iron ore and calcined to cone 18, increased in weight 3% at the end of 80 days, while that prepared from 100 mesh dolomite and calcined to cone 20, increased in weight 1.5% at the end of 80 days. Increasing the calcination temperature again increases the tendency of the dolomite to take up moisture and CO_2. This agrees with the results obtained with flue dust and follows since flue dust and iron ore show similar chemical analyses.

Where dolomite is ground to 40 mesh size and calcined to cone 26 (see figure 4) it appears that increasing the iron oxide content up to 10% decreases the tendency to increase in weight. Adding 15% increases the tendency to take up moisture and CO_2 as compared to 10% mixtures. With a 20% addition decrease occurs, while adding 25% and 30% again increases the tendency to increase in weight. The effects produced by flue dust on 40 mesh dolomite are similar to those obtained with iron ore (see figure 2). Also, as was the case with flue dust, the mixture prepared from 100 mesh dolomite and calcined to cone 14 showed an increase in the tendency to take up moisture and CO_2 when prepared from mixtures high in iron ore. After calcining to cones 20 and 26, however, increasing the iron ore content decreases the tendency to increase in weight. These results also check with those obtained with flue dust (see figure 1).

Iron Ore and Magnesite.—Figure 5 shows the effects of different calcining temperatures on the increase in weight of

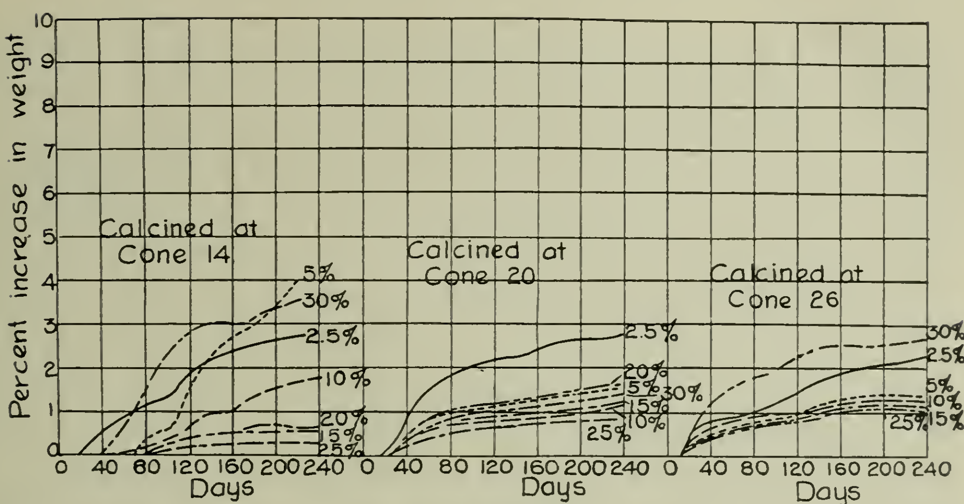

FIG. 5.—The effect of iron ore on the stability of magnesite after calcining at different temperatures. Magnesite and iron ore through 100 mesh.

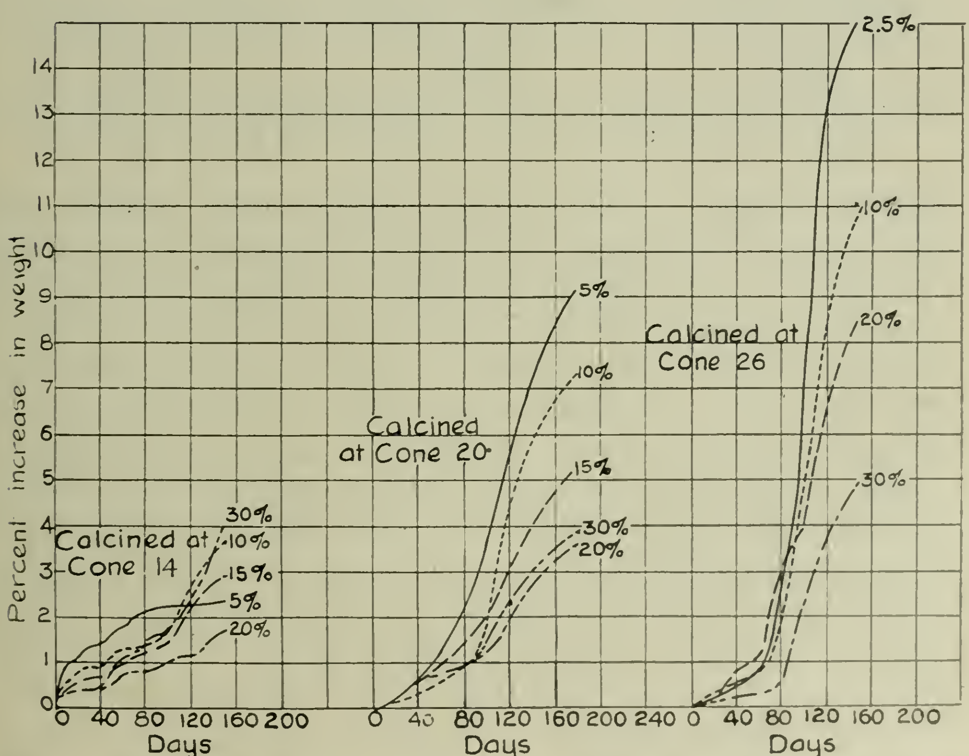

FIG. 6.—The effect of basic open-hearth slag on the stability of dolomite after calcining at different temperatures. Dolomite and slag through 100 mesh.

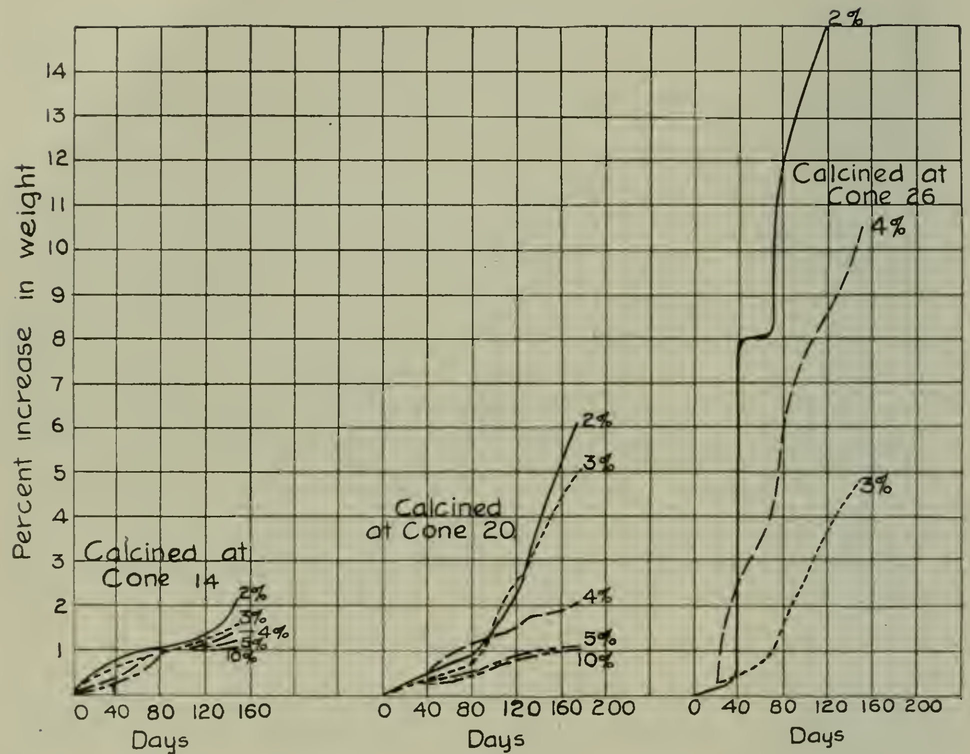

FIG. 7.—The effect of kaolin on the stability of dolomite after calcining at differen temperatures. Dolomite and kaolin through 100 mesh.

Canadian magnesite and iron ore mixtures after storage. In most instances increasing the calcination temperature decreases the tendency of magnesite to increase in weight, although with those mixtures prepared from 15%, 20% and 25% iron ore, there is a slight increase in the tendency to take up moisture and CO_2 from the air after calcining at the higher temperatures. The magnesite employed contains 11% CaO. It shows a less tendency to slake than dolomite, due to the higher content of MgO which is comparatively easy to place in a dead burned condition. A mixture prepared from 10% iron ore with 100 mesh dolomite and calcined to cone 20 increased in weight 3.3% at the end of 160 days while the same percentage mixture with 100 mesh magnesite increased in weight only 0.85% which may be principally hygroscopic moisture.

Basic Open Hearth Slag and Dolomite.—Figure 6 shows the effects of fine grinding and different calcination temperatures

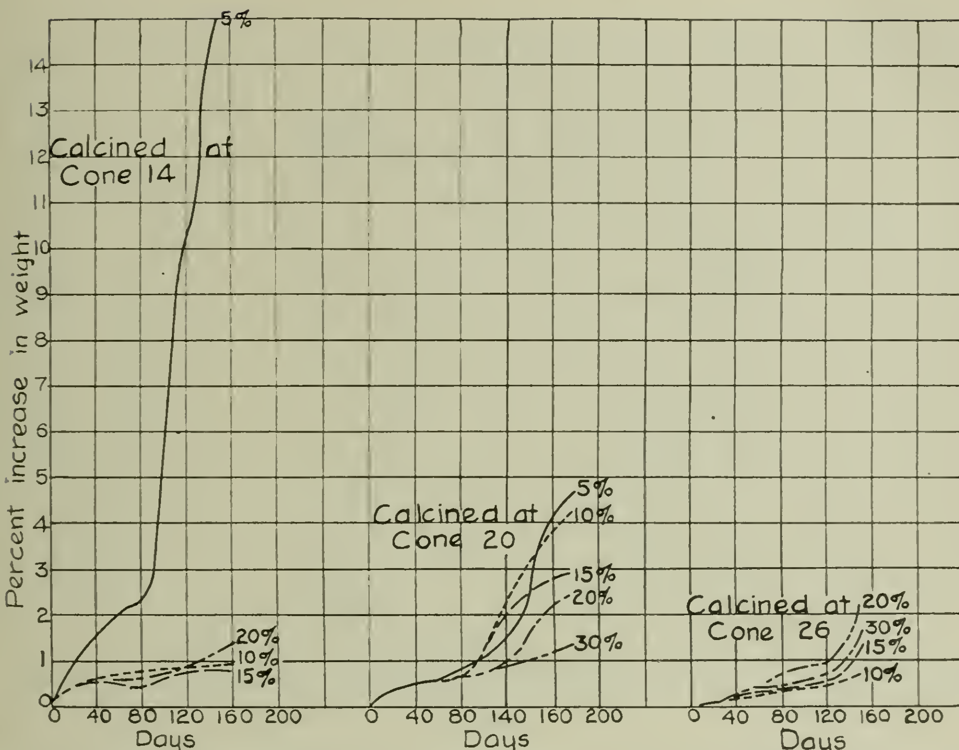

FIG. 8.—The effect of roll scale on the stability of dolomite after calcining at different temperatures. Dolomite and roll scale through 100 mesh.

on the tendency to increase in weight on storage. When a mixture prepared from 15% basic open hearth slag and 8 mesh dolomite is calcined to cone 18 it increases in weight 10.8% at the end of 80 days, whereas a similar mixture with 100 mesh dolomite, and calcined to cone 20 increases in weight only 1.4% in the same time interval.

Here again increasing the calcination temperatures increases the tendency of the calcined material to increase in weight. With basic open hearth slag as a flux, the high fired mixtures showed a greater tendency to increase in weight than with iron ore and flue dust as fluxes. This may be due to the lime and silica content of the slag which forms unstable compounds with the CaO of the dolomite.

Kaolin and Dolomite.—Figure 7 shows the effects of fine grinding and different calcination temperatures on the tendency of dolomite-kaolin mixtures to increase in weight. Increasing

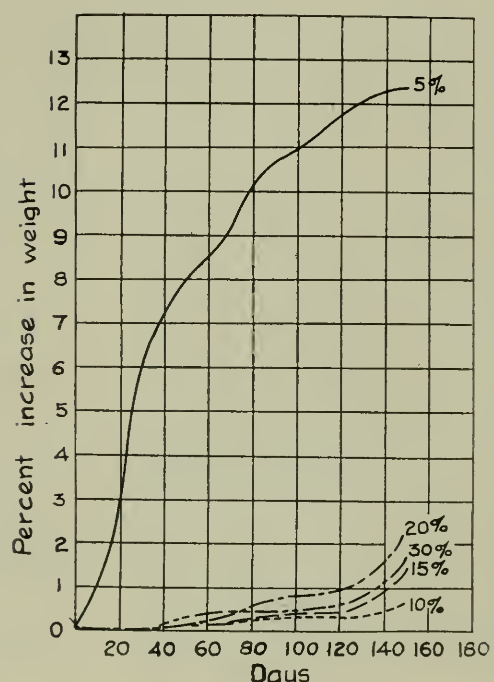

FIG. 9.—The effect of roll scale on the stability of dolomite after burning to cone 26. Dolomite through 40 mesh; roll scale through 20 mesh.

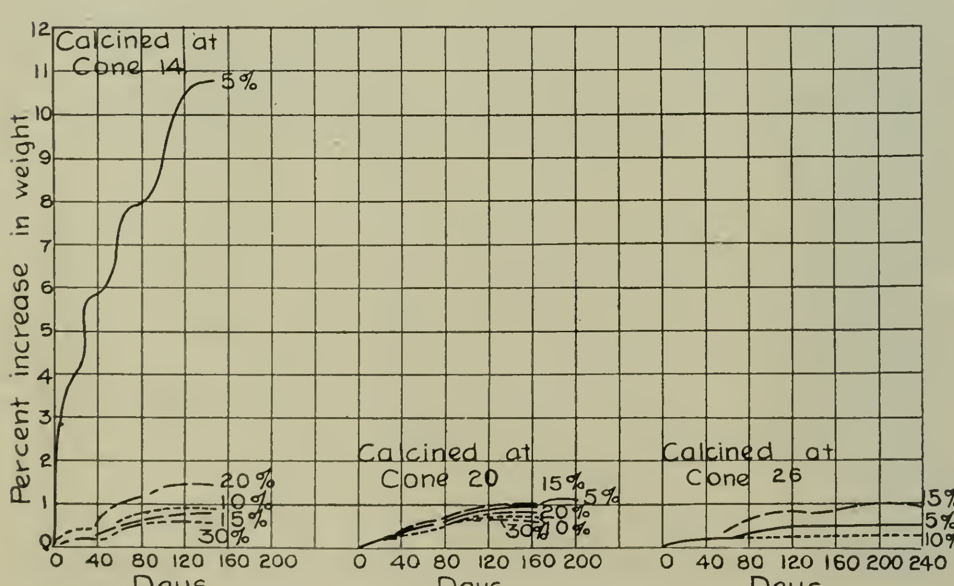

FIG. 10.—The effect of roll scale on the stability of magnesite after calcining at different temperatures. Magnesite and roll scale through 100 mesh.

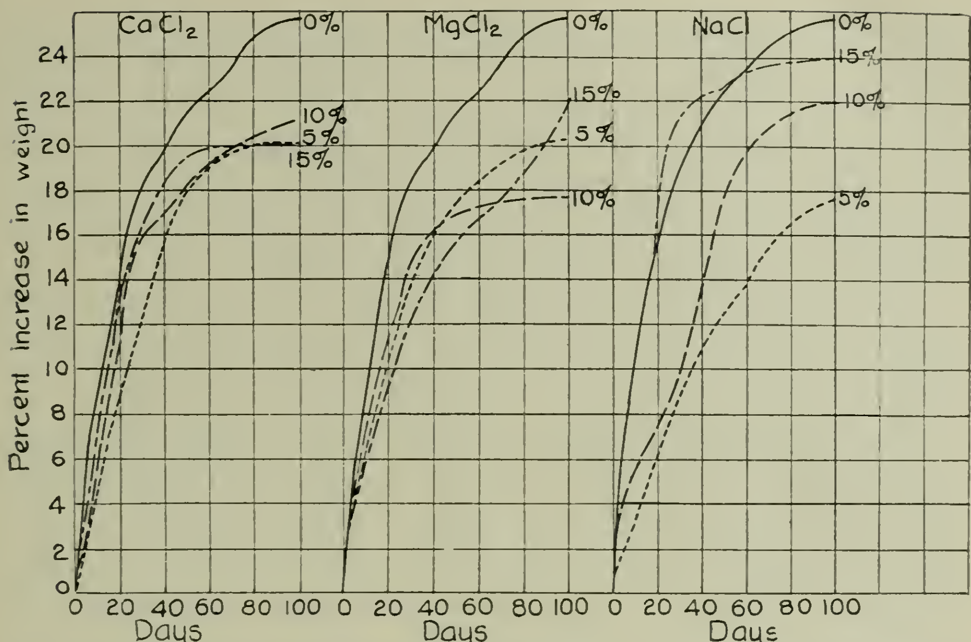

Fig. 11.—The effect of chlorides on the stability of dolomite after burning to cone 14. Dolomite through 8 mesh. Chloride through 20 mesh.

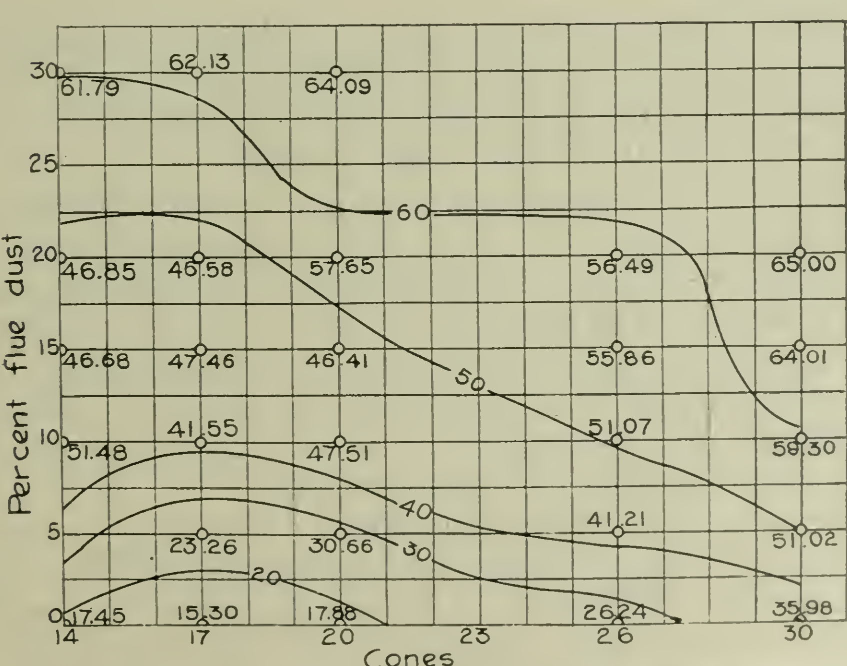

Fig. 12.—Burning, shrinkage, diagram. Dolomite—flue-dust mixtures.

the calcination temperatures again increases the tendency of the calcine to increase in weight. The increase in weight during storage is more pronounced on the high fired specimens than with the corresponding iron ore and flue dust mixtures. This is probably due to the comparatively high silica-alumina content of the kaolin which evidently forms hydraulic compounds with the lime similar to those found in Portland cement.

Finer grinding of the dolomite increases the resistance of the calcine towards moisture and CO_2, producing a more stable product than that obtained with coarser raw materials.

Roll Scale and Dolomite.—Figures 8 and 9 show the effects of calcination temperatures on the tendency of dolomite-roll scale mixtures to increase in weight. When mixtures of 15% roll scale and 8 mesh dolomite are calcined to cone 18, they increase in weight 5.5% at the end of 80 days[1] and where 100 mesh dolomite is employed with 15% roll scale and calcined to cone 20 the increase in weight is only 0.6% at the end of 80 days.

With roll scale, increasing the calcination temperature does not materially change the tendency of the product to take up moisture and CO_2.

Where the raw dolomite is screened through a 40 mesh sieve before mixing with roll scale and is calcined to cone 26, the mixture containing the highest per cent of roll scale increases in weight more than those containing a lower per cent.

Roll Scale and Magnesite.—Figure 10 shows the effects of varying percentages of roll scale and calcination temperatures on the tendency of roll scale magnesite mixtures to increase in weight during storage. Increasing the calcination temperature decreases the tendency to increase in weight. The comparatively small increase in weight of calcined magnesite mixtures as compared to calcined dolomite mixtures shows that calcined magnesite is much more stable than calcined dolomite.

In comparing the effects of roll scale on the slaking of magnesite to those of iron ore (see figure 5) it is obvious that the former is much more effective as a dead-burning agent for magnesite than the latter. This is probably due to the lower silica and

[1] *Loc. cit.*, p. 301.

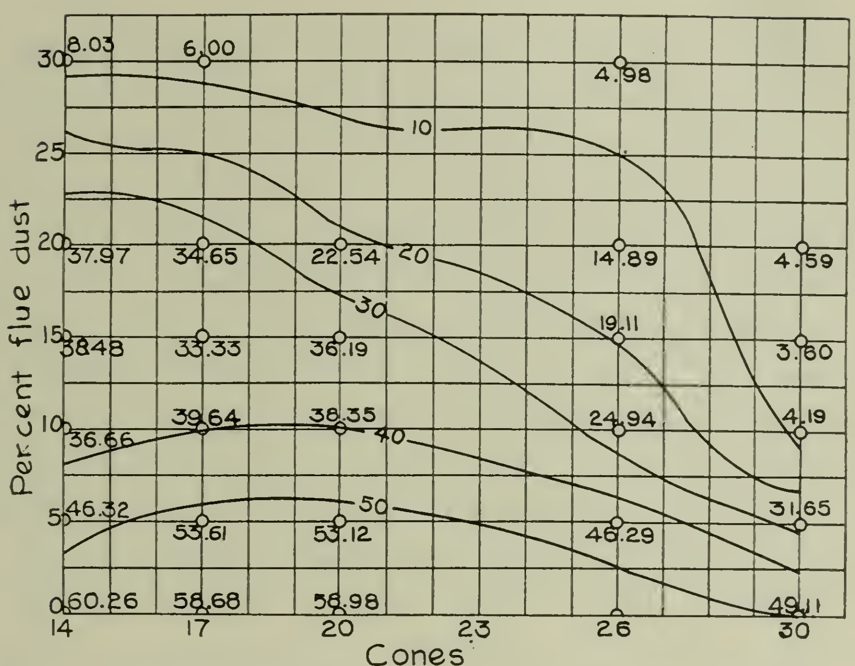

FIG. 13.—Burned porosity diagram. Dolomite—flue-dust mixtures.

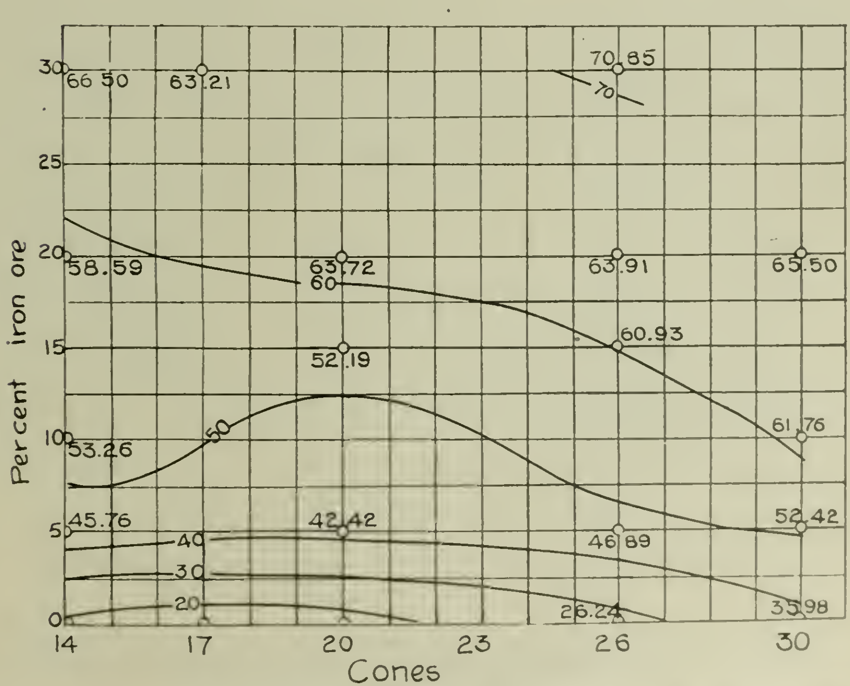

FIG. 14.—Volume, shrinkage, diagram. Dolomite iron-ore mixtures.

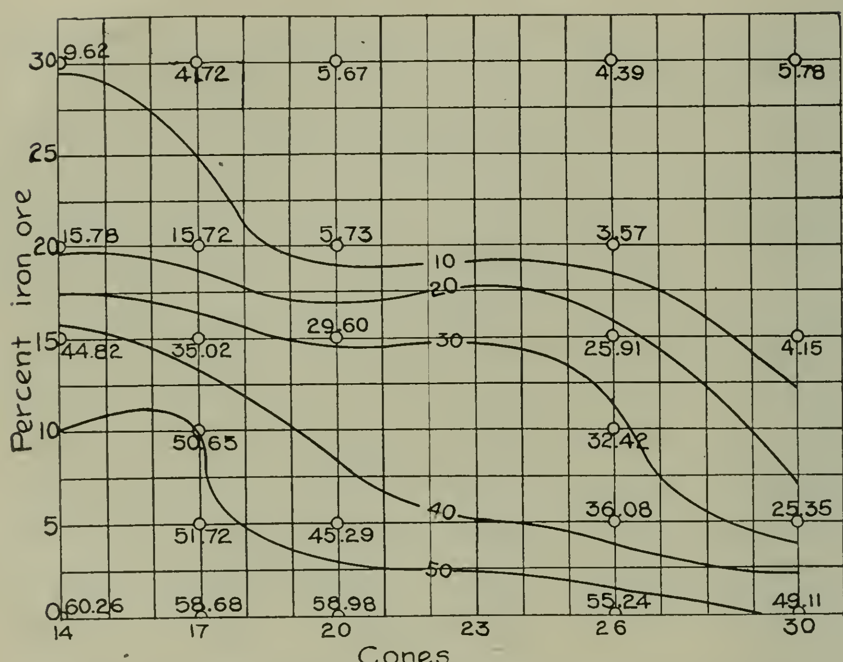

FIG. 15.—Porosity diagram. Dolomite—iron-ore mixtures.

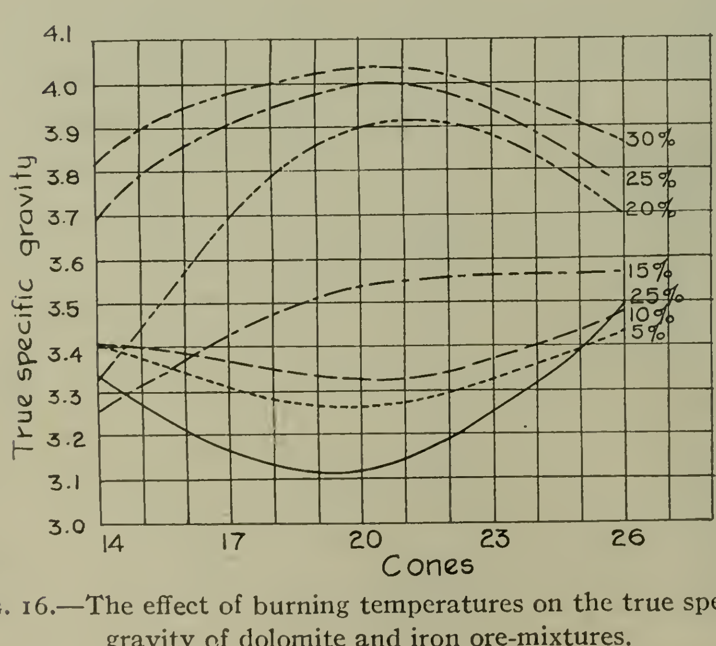

FIG. 16.—The effect of burning temperatures on the true specific gravity of dolomite and iron ore-mixtures.

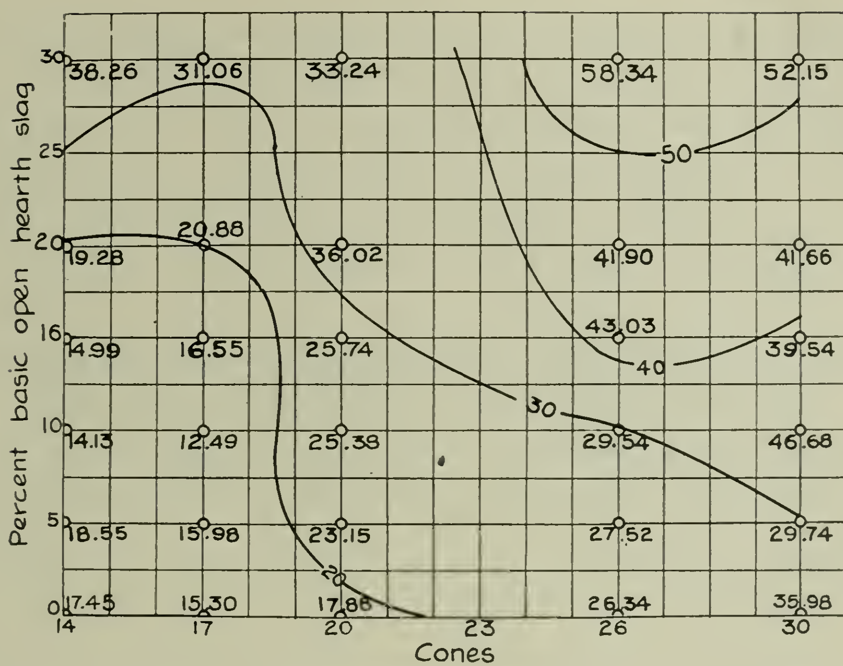

FIG. 17.—Volume shrinkage. Dolomite—basic open-hearth slag mixtures.

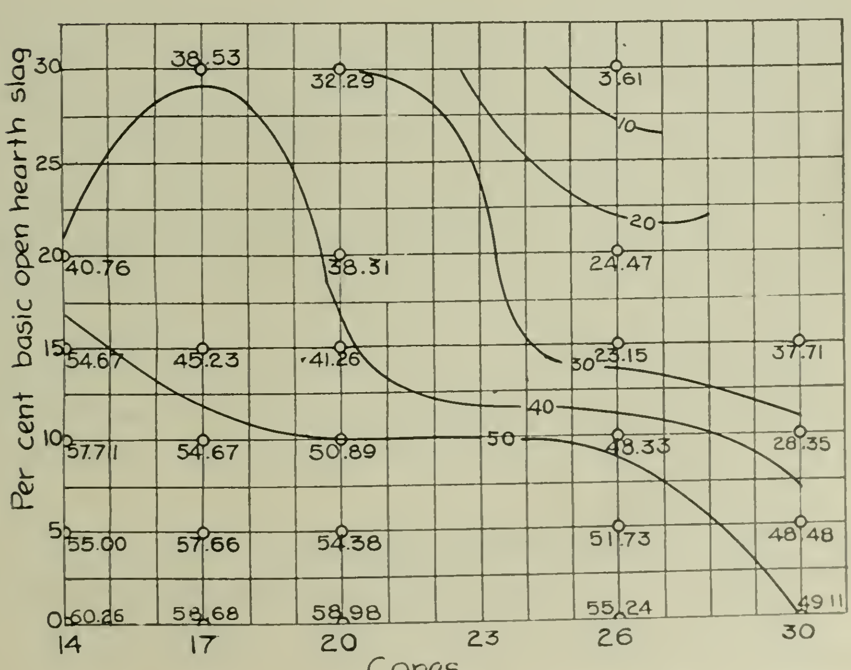

FIG. 18.—Burned porosity diagram. Dolomite—basic, open-hearth slag mixtures.

alumina content of the roll scale as silica and alumina tend to form unstable compounds with the lime of the magnesite.

Chlorides and Dolomite.—Figure 11 shows the results obtained by adding chlorides to 8 mesh dolomite and calcining to cone 14. Although the slaking is decreased to a slight extent, the benefits derived within the limits covered are too small to justify their use.

Effects of Different Fluxes and Calcining Temperatures on the Shrinkage and Porosity of Dolomite and Magnesite

Flue Dust and Dolomite.—Figures 12 and 13 show the effects of varying percentages and calcination temparatures on the shrinkage and porosity of the mixtures. To get maximum shrinkage and minimum porosity it is necessary to calcine a mixture of 30 per cent flue dust and 70 per cent raw dolomite to cones 14–20. It is necessary to calcine the mixture prepared with 25 per cent flue dust to cone 26 and the mixture with 10 per cent flue dust to cone 30 in order to obtain the same results.

Iron Ore and Dolomite.—Figures 14 and 15 show the effects of varying iron ore and temperatures of calcination on dolomite-iron ore mixtures. The behavior of iron ore is very similar to that of flue dust, which might be anticipated owing to their similarity in chemical analysis.

Figure 16 shows the true specific gravities of iron ore-dolomite mixtures when calcined at different temperatures. To obtain maximum specific gravity it is necessary to calcine mixtures with 2.5%, 5% and 10% iron ore to cone 26. That with 15% iron ore requires calcining to cones 20 or 26; and those with 20%, 25% and 30% to cone 20. When the high iron ore mixtures are calcined to cone 26, the specific gravity decreases, which may be due to over-burning.

Basic Open Hearth Slag and Dolomite.—Figures 17 and 18 show the effects of basic open hearth slag on dolomite mixtures when calcined at different temperatures. Vitrification is more dependent upon higher calcining temperatures than was the case with iron ore or flue dust. For example, a mixture containing 30 per cent basic open hearth slag must be calcined to cone 26

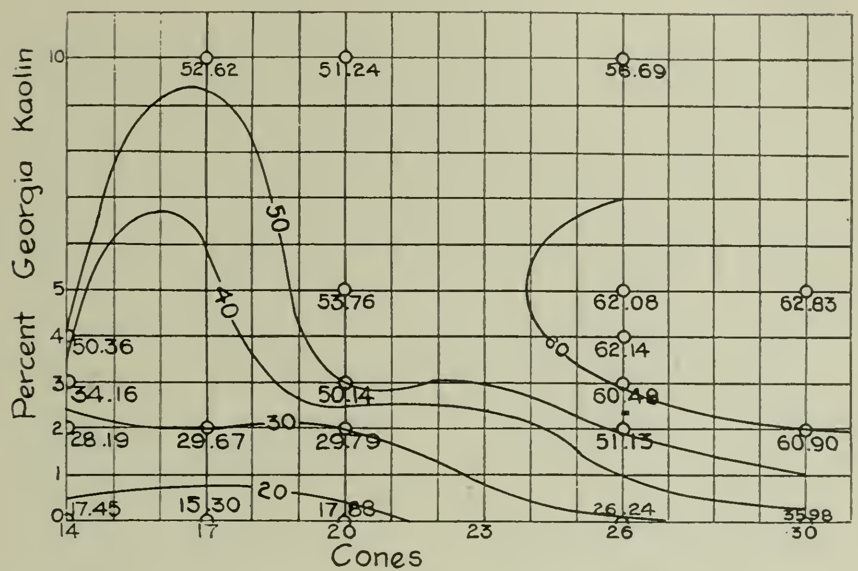

FIG. 19.—Volume shrinkage diagram. Dolomite—kaolin mixtures.

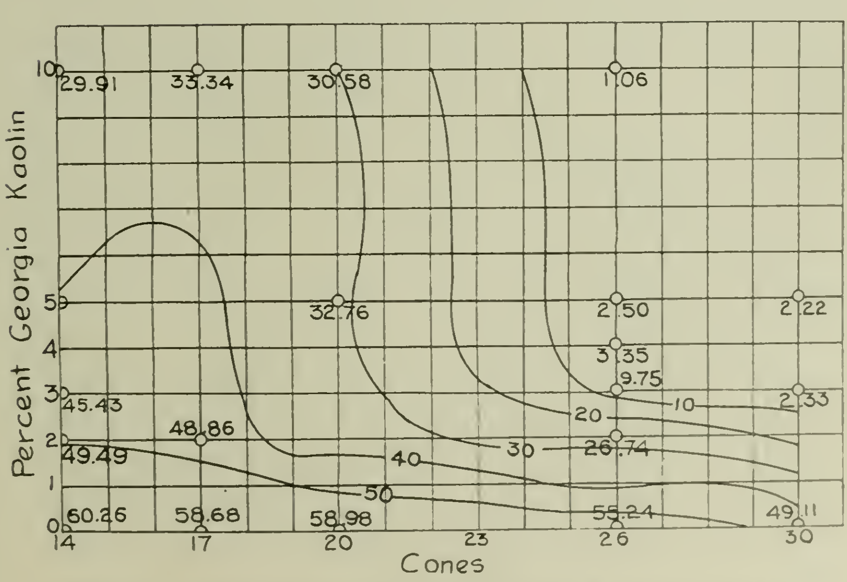

FIG. 20.—Porosity diagram. Dolomite—kaolin mixtures.

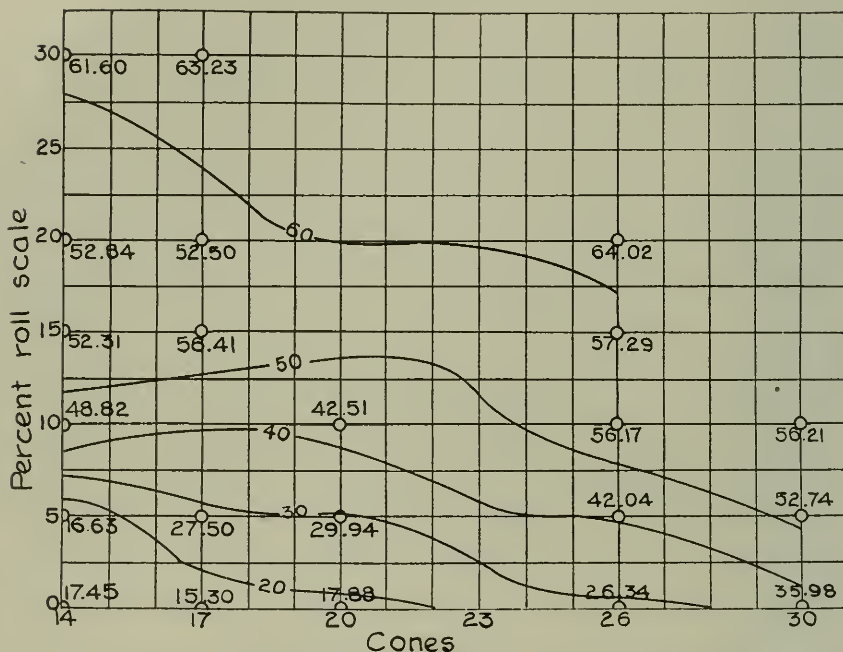

FIG. 21.—Volume shrinkage diagram. Dolomite—roll-scale mixtures.

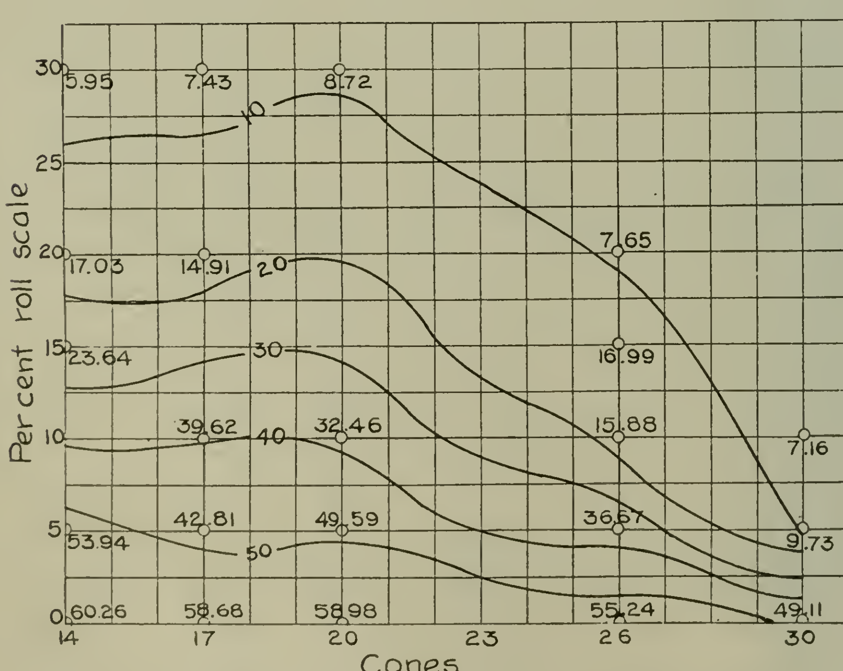

FIG. 22.—Porosity diagram. Dolomite—roll-scale mixtures.

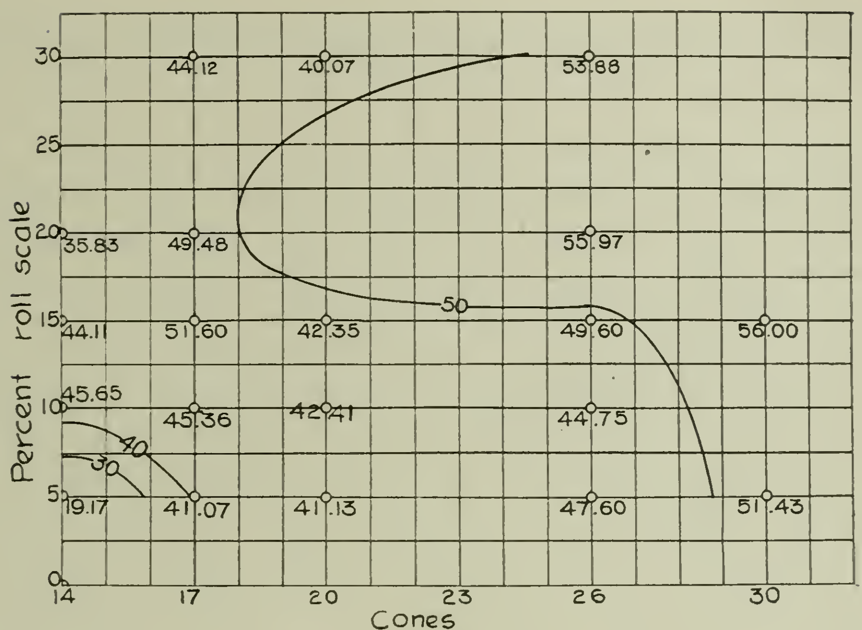

FIG. 23.—Burning, shrinkage, diagram. Magnesite—roll-scale mixtures.

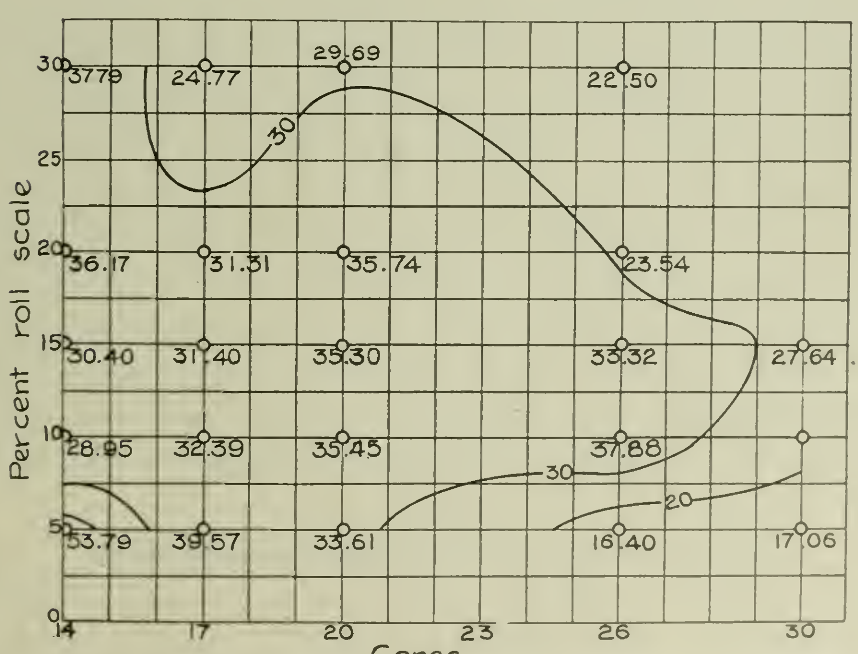

FIG. 24.— Burned porosity diagram. Magnesite—roll-scale mixtures.

to become vitrified, whereas a mixture containing 30 per cent iron ore or flue dust becomes vitrified at cone 14, (See figures 11, 12, 13 and 14).

Kaolin and Dolomite.—Figures 19 and 20 show the effects on shrinkage and porosity of Georgia kaolin and calcining temperatures on dolomite-kaolin mixtures. The vitrification is more dependent upon the calcining temperature than on the kaolin content when compared to flue dust and iron ore mixtures. Also kaolin is more effective than an equal weight of iron ore or flue dust in promoting vitrification. This is probably due to the higher silica content of the flux which combines readily with lime, forming lime silicates with a high per cent of lime, as $2CaO.SO_2$ and $3CaO.SiO_2$. For example, 5% kaolin and 95% dolomite has a porosity of 33.95% when calcined to cone 14 and is reduced to 2.50% porosity when calcined to cone 26, while a mixture of 5% flue dust and 95% dolomite has a porosity of 46.32% when calcined to cone 14 and 46.29% when calcined to cone 26.

Roll Scale and Dolomite.—Figures 21 and 22 show the effects of roll scale and calcining temperatures on the shrinkage and porosity of dolomite-roll scale mixtures. These diagrams are somewhat similar to those obtained with flue dust and iron ore. Bodies containing 30 per cent roll scale become vitrified at cones 14–20; those containing 20 per cent, at cone 26; and those containing 5–10 per cent are vitrified by calcining to cone 30.

Roll Scale and Magnesite. Figures 23 and 24 show the effects of roll scale and calcining temperatures on the shrinkage and porosity of magnesite-roll scale mixtures. It is seen that the shrinkage is much less and the porosity much greater with magnesite as compared to dolomite. The lime in the dolomite is more actively attacked by roll scale than the magnesia, which would account for the greater resistance of magnesite towards the corrosion of basic slags.

Results Obtained in Making Dolomite Brick

The mixtures of dolomite and iron ore were ground through a 100 mesh sieve and calcined to cone 20 in an air-gas furnace. As binders, one portion was mixed with 5% caustic lime, another

with 5% sodium silicate, and a third with 5% magnesium chloride. These batches were thoroughly pugged in a wet pan and brick were molded by hand. Upon drying, all of the brick cracked, due to slaking.

To overcome the cracking, the above batches were aged with an excess of water for at least three weeks. The ageing caused the batch to expand considerably due to slaking. Brick made from the aged material could be dried safely, since hydration had taken place, hence no cracking due to hydration occurred in drying. Those made with magnesium chloride were very strong on drying, due to the formation of Sorel cement.

When these brick were fired to cone 18 they, however, showed excessive cracking due to high shrinkage in firing. These brick were extremely dense and withstood storage from four to six months when they began to show disintegration due to air slaking.

The next series of brick were made with coal tar as a binder. The calcined dolomite was ground to pass a 40 mesh sieve and mixed while hot with 12% coal tar which had previously been dehydrated by heating to 200°C. The brick were formed while still hot under a pressure of 500 pounds per square inch. By selecting a tar which becomes hard on cooling, brick with sufficient mechanical strength to withstand handling and shipping may be made without burning. Tar-bonded brick will stand storage about four months, after which they begin to disintegrate.

The tar-bonded brick when fired show less shrinkage and cracking than those prepared with water, since no hydration has taken place. It is desirable to dip dolomite brick in tar as soon as taken from the kiln in order to prevent rapid disintegration. Brick made in this manner withstand storage five to six months before showing signs of disintegration.

In conclusion the writer wishes to acknowledge his indebtedness to Mr. R. T. Stull for assistance in this work.

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Mining Experiment Station, Columbus, Ohio

Notice—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

NORMAL CONSISTENCY OF SANDED GYPSUM PLASTER[1,2]

By W. E. Emley and C. F. Faxon

ABSTRACT

Variation of tensile strength of sanded gypsum plasters with composition and consistency before setting.—To each of a series of 12 plasters, containing various proportions of sand, 5 different amounts of water were added. The consistencies, determined by means of a Southard viscosimeter, and the tensile strengths of the set plasters are tabulated. The results vary both with the kind of gypsum and with the fineness of the sand.

Suggested method of determining normal consistency of sanded gypsum plasters.—As a result of considerable experience the authors have reached the conclusion that material of the proper consistency to be used for plastering will show a slump of $^1/_2$ inch when tested in the Southard viscosimeter.

The Southard viscosimeter, which is used for measuring the consistency of gypsum plasters, is described in detail in the "Tentative Methods for Tests of Gypsum and Gypsum Products," published by the American Society for Testing Materials as No. C 26–19 T, in 1919. In this Tentative Method, it is stated that a mixture (of the sample and water) is of normal consistency if when tested by the Southard viscosimeter, it gives a circular patty averaging 9.7 cm in diameter.

This figure, 9.7, is purely empirical, but there are several good reasons for its adoption. The consistency does not vary directly with the amount of water: the relation between the two is probably logarithmic, as is the case in many similar relations. The particular consistency represented by the figure 9.7 is such that small variations in the amount of water make large variations in the consistency. This permits the normal consistency to be determined with a probable error of less than one per cent. From a practical viewpoint, this normal consistency may be stated to be about right for gypsum mortar or for reinforced gyp-

[1] Received September, 1920.

[2] Published by permission of Director, Bureau of Standards.

sum. It is possibly a little too thin for plaster. In this Tentative Method, no distinction is made between neat gypsum plasters and those containing sand.

During 1919, forty-three gypsum plaster were tested, in research work conducted by this Bureau.[1] Five of these samples were "ready mixed"—that is, they contained sand. It was found that a sanded plaster having the same consistency as a neat plaster when measured by the Southard viscosimeter, was in reality noticeably wetter. The above arguments in favor of the figure 9.7 no longer hold, and it was decided to establish a new figure for sanded plasters. At its 1920 meeting, the American Society for Testing Materials granted permission to revise the Tentative Methods to this effect. The Bureau of Standards was requested to develop sufficient data to be used as a basis for setting this new figure.

For this purpose the following program was carried out: Two kinds of calcined gypsum, and two kinds of sand were selected. Each gypsum was mixed with each sand, making four series. The proportions used were 1 : 1, 1 : 2 and 1 : 3 parts of gypsum by volume to parts of sand. This made 12 mixed plasters. Each plaster was tested at 5 different consistencies. The amount of water which could be added to make the material as dry as it could be worked and as wet as it could be worked, respectively, were found by trial and, in addition, three intermediate consistencies were used. The tests comprised noting the apparent consistency, measuring the consistency by means of the Southard viscosimeter, and measuring the tensile strength of the set plaster. The results are shown in the following table:

Properties of the Calcined Gypsums

	No. 1	No. 2
Chemical composition:		
Calcium oxide	35.72	38.90
Carbon dioxide	15.20	0.70
Sulphur trioxide	35.90	53.60
Loss on ignition	20.05	7.55
Calcined gypsum (calculated)	42.38	97.15
Normal consistency—cc water per 100 grams	44.6	61.0
Time of set	5 hrs. 37 m.	9 m.

[1] Physical Properties of Commercial Gypsum Plasters, by Emley and Faxon, This Journal, December, 1920,

Fineness:		
Residue on No. 8 sieve, per cent	0	0
Through 8, retained on 14	0	0
Through 14, retained on 30	0	0
Through 30, retained on 50	1.7	0.3
Through 50, retained on 100	14.1	4.9
Through 100, retained on 200	10.3	13.2
Through 200	73.9	81.6
Yield:		
Lbs. paste per cu. ft	120	92
Lbs. dry material per cu. ft. paste	83	57
Lbs. set material per cu. ft	87	78
Strength, lbs. per sq. in.:		
Compressive	1400	1720
Tensile	129	270

Screening Analyses of the Sands

Per cent retained on No. 14 sieve	0	0
Per cent passing No. 14 and retained on No. 30	16.0	0
Per cent passing No. 30 and retained on No. 50	46.7	46.9
Per cent passing No. 50 and retained on No. 100	22.9	40.0
Per cent passing No. 100 and retained on No. 200	6.5	8.5
Per cent passing No. 200 (by difference)	7.9	4.6

Results of Tests

Gypsum No.	Sand No.	Proportions by volume	Cc water per 100 grams dry material	Apparent consistency	Consistency by Southard machine. Cms. diam. of pat.	Tensile strength, lbs. per sq. in.
1	1	1:1	22	stiff	no slump	119
			24	thick	8.8	97
			26.5	medium	12.5	82
			29	thin	15.5	72
			31	very thin	17	69
		1:2	18	stiff	no slump	90
			21	thick	bulged	69
			24	medium	10.7	53
			27	thin	15.6	41
			30	very thin	17.1	25
		1:3	19	stiff	no slump	30
			21	thick	bulged	31
			23	medium	9.7	17
			25	thin	13.4	11
1	2	1:1	23	stiff	no slump	104
			26	thick	bulged	86
			28	medium	10.0	79
			31	thin	12.9	79
			34	very thin	16.4	65

		1:2	20	stiff	no slump	48
			24	thick	bulged	33
			27	medium	9.8	29
			30	thin	14.7	30
			33	very thin	16.4	19
		1:3	17	stiff	no slump	44
			20.5	stiff	no slump	16
			24	thick	bulged	17
			27.5	medium	10.7	a
			30	thin	12.3	a
			31.3	thin	14.3	15
			32	thin	15.1	a
			33	very thin	16	a
2	1	1:1	12	stiff	no slump	240
			25	thick	bulged	74b
			28	medium	10	149
			32	thin	16.4	135
			34.5	very thin	18.1	130
		1:2	16.6	very stiff	no slump	a
			20	stiff	no slump	134
			22.3	thick	bulged	136
			24.6	medium	9.9	100
2	1	1:2	27	thin	13.5	96
			29.5	very thin	16.2	86
		1:3	17	very stiff	no slump	a
			21	thick	no slump	110
			24	medium	9.1	62
			27	thin	14.1	67
			30.6	very thin	16.8	60
2	2	1:1	22	stiff	no slump	223
			26	thick	bulged	266
			30	medium	11.9	182
			33	thin	14.4	153
			37	very thin	17.3	125
		1:2	20	stiff	no slump	128
			24	thick	bulged	92
			28	medium	10.9	102
			32	thin	16.7	92
			35.3	very thin	17.5	79
		1:3	20	stiff	no slump	56
			23	thick	bulged	63
			27	medium	8.8	56
			29.3	thin	14.4	54
			33.3	very thin	17.4	40

NOTES: All figures for tensile strength are the average of at least three determinations, usually of six, and sometimes of nine.

a.—These specimens were so weak that they could not be put in the machine.

b.—Evidently erroneous. Reason not known.

It must be confessed that the information contained in the above table is chiefly negative when considered as an answer to the question investigated. However, the intimate acquaintance with the Southard viscosimeter which has been gained in this research, and in the one cited above, does enable us to make a definite recommendation.

The Southard machine is designed to push the material vertically upwards out of a well, in such a way that it will overflow and spread out on a horizontal plate. This plate is graduated so that the final diameter of the pat can be measured. If the consistency of the material is very thin, the pat will tend to take the form of a plane. As the consistency is made thicker, through a comparatively long range, the final shape of the pat approximates the frustrum of a cone. The sides of this cone are concave instead of being straight, and they become more nearly vertical as the consistency becomes thicker. The "normal" consistency of 9.7 is near the thicker end of this range. If the consistency is a little thicker than 9.7, the material does not overflow on the plate. Instead, it bulges, so that its final form is that of a barrel. While the original diameter of the material as it comes from the well is such that it should be possible to get a reading of about 6 cm, we have never been able to get a reading much less than 9 cm. A material of such consistency that it should spread out to 7 cm diameter, for example will not spread at all, but will bulge instead.

As the consistency is made still thicker, the bulge becomes less pronounced, until finally it is not noticeable: the material retains the cylindrical form of the well. This is about the practical limit of consistency. Drier material is crumbly and can not be used.

The consistency used by plasterers is towards the thinner end of the bulging range. The graduations on the plate of the Southard viscosimeter can not be used to measure such a consistency. We can, however, have recourse to the "slump" method which was formerly used for measuring the consistency of concrete. We

can measure the decrease in the height of the specimen rather than its increase in diameter.

As a result of considerable experience, gained by using the Southard viscosimeter by five operators, during two years, on all kinds of plastering materials, it is our opinion that material of the proper consistency to be used for plastering will show a slump of $^1/_2$ inch when tested in this machine. That is, the final height of the specimen will be two inches. This applies to sanded plasters only, mixed ready for scratch or brown coat work. For the neat materials used for finish coats, the original figure of 9.7 cm is satisfactory.

CERAMIC ABSTRACTS[1]

Author Index to Abstracts for February

[1] The abbreviation (C. A.) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. **Belting for power transmission.** ERNEST D. WILSON. Mellon Institute. *Trans. Am. Inst. Chem. Eng.*, 11, 237–48 (1918).—Methods of testing: h. p. slip and effective pull curves are given with a discussion.

JAMES R. WITHROW (C. A.)

2. **Silicate paints.** CH. COFFIGNIER. *Rev. chim. ind.*, 28, 299–301 (1919).—The method used in the lab. of the technical section of the Artillery for the *analysis of fireproofing paints* with a base of Na silicate, is outlined. 1. The sample is extd. with warm H_2O and filtered on a tared paper. The residue is called pigment. 2. The filtrate is titrated to Me orange with 0.5 *N* HCl. The result is expressed as Na_2O. Addition of the equiv. amt. of SiO_2 gives the amt. of *Na silicate* present. 3. *Water* is detd. by difference. 4. The examn. of the pigment varies with its nature. T. G. PHILLIPS (C. A.)

3. **Asbestos in the paint industry.** G. B. HECKEL. *Asbestos*, 2, 5–10 (1920); *Drugs, Oils and Paints*, 36, 141–2 (1920).—G. gives the legitimate uses for inert or reinforcing pigments in paints, with particular attention to asbestiform pigments, derived from chrysotile. A fire-retardane paint for shingle roofs, adopted by the Natl. Lumber Manufs. Assoc., contains 33 per cent asbestine. F. A. WERTZ (C. A.)

4. **Talc in fire-resistant paint.** RAYMOND B. LADOO. *Drugs, Oils and Paints*, 36, 144(1920).—Asbestine is not the chrysotile variety of asbestos but is a fibrous variety of talc. See preceding abstr. G. A. WERTZ (C. A.)

5. **Paints for iron which is exposed to high temperatures.** K. NICKSCH. *Z. Ger. Kohleus. Ind.*, 1919; *Rev. chim. ind.*, 28, 267 (1919).—Pure graphite is satisfactory for coatings of furnaces, autoclaves, etc., which are alternately heated and cooled. For good appearance and resistance to very high temps. sodium silicate has proved very efficient. Vessels subjected to even temps. may be protected by a hot application of a mixt. of 500 g. of melted lard and 16 g. of powdered camphor with enough pure powdered graphite to give a dark color. The excess which does not penetrate should be scraped off after 24 hrs. Cast-iron rust forms a coating which protects the body of the iron from further oxidation. Wrought iron forms no such protective rust but a covering with an iron oxide base, as red ochre, is resistant to acids and fumes at high temps. Walls of furnaces and chimneys where low temps. prevail may be painted with a thin coat of a pitch and tar mixt. which has been heated and to which 2 to 3 per cent of milk of lime and a little asphalt has been added. It may be dild. with turpentine. This makes a resistant coating which acquires an excellent luster. "*Durabo*" is a com. heat-resisting paint which must be preceded by a coat of red lead or iron oxide. Varnishes and drying paints can not be used, as they crack with temp. changes. Paints should be applied only to perfectly clean surfaces. Previous coats should be removed with 50 per cent carbolic acid soln. Rusted spots should be treated with 5 per cent HCl, followed by a rinsing with a dil. soda soln. After

thorough drying the surface should be polished with emery cloth or rottenstone. This thorough cleansing is very important. As base for the paint a thin coat of varnish or linseed oil may be applied. C. B. EDWARDS (C. A.)

BOOKS

6. LACROIX, A.: **Les industries minérales non métallifères a Madagascar.** Paris Editions de la Revue politique et littéraire. (C. A.)

Apparatus and Instruments

7. **The construction of thermocouples by electrodeposition.** WM. H. WILSON AND MISS T. D. EPPS. *Proc. Phys. Soc. London*, **32**, 326–40 (1920).—If a wire of constantan, or other metal of high resistance, is plated with a sufficient thickness of Cu or Ag, the plated portion becomes a compound wire whose thermal e. m. f. against the unplated portion is nearly as great as for the pure Cu or Ag. A plating from 25 to 35 per cent of the cross-section of the original wire is recommended. [The e. m. f. with constantan is then probably not over 14 per cent less than with pure Ag and constantan.—ABST.] By winding the original wire in a helix and plating one side of this, a series of plated and unplated pairs is obtained, forming a multiple-junction *thermel* (thermoelement). Very fine thermels can thus be made with very great ease. In one case a thermel of 4000 couples was made, whose hot end was less than 1.6×4 cm. W. P. WHITE (C. A.)

8. **The disappearing-filament type of optical pyrometer.** W. E. FORSYTHE. Nela Laboratory. *Trans. Faraday Soc.*, **15**, Pt. 3, 21–53 (1920).—A careful explanation, apparently intended especially for those not familiar with the instrument, and laying emphasis on its advantages. W. P. WHITE (C. A.)

Chemistry, Physics and Geology of Ceramic Raw Materials

9. **Constitution of the silicates.** JOHANN JAKOB. *Helvetica, Chim. Acta*, **3**, 669–704 (1920); cf. *C. A.* **14**, 917.—By a comprehensive comparative study of the transformation products of minerals their constitution is deduced. The silicates are here formulated according to the Werner principles. The prototype is considered to be $[SiO_6]R_8$ which dissociates easily at high temps. to coördinatively unsatd. penta- and tetra-oxysilicates which easily polymerize to higher forms, *e. g.*, asperolith, CuH_6SiO_6; chrysocolla, CuH_4SiO_5; dioptase, CuH_2SiO_4. Adjacent pairs of O atoms at the octahedron corners can add SiO_2 forming mono-, di- and tri-hexoxysilicates and pairs of H atoms in the outer sphere have residual affinity sufficient to hold water mols., forming the group $\begin{matrix}\mathrm{H} & & \mathrm{H}\\ & >\mathrm{O}< & \\ \mathrm{H} & & \mathrm{H}\end{matrix}$; *e. g.*, serpentine, $\left[\mathrm{SiO_2.SiO_6}\right]^{\mathrm{Mgs.}}_{\mathrm{H_2.OH_2}}$; deweylite, $\left[\begin{matrix}\mathrm{SiO_2} & \\ & \mathrm{SiO_6}\\ \mathrm{SiO_2} & \end{matrix}\right]^{\mathrm{Mg_2}}_{\mathrm{(H_2OMg)_2}}$ diopside, $\left[\mathrm{Si}\begin{pmatrix}\mathrm{O} & & \mathrm{O}\\ & \mathrm{Si} & \\ \mathrm{O} & & \mathrm{O}\end{pmatrix}_3\right]^{\mathrm{Mg_2(Fe)}}_{\mathrm{Ca_2}}$. The octahedral formulation predicts the possibility of optical isomers in the two latter cases.

Further SiO_2 groups can add upon 3,SiO_2 groups of $[(SiO_2)_3.SiO_6]R_8$ forming the types $[(O_2SiO_2)_2Si(O_2SiO_2SiO_2)]R_8$; $[(O_2SiO_2)Si(O_2SiO_2SiO_2)_2]R_8$ and $[Si(O_2SiO_2SiO_2)_3]R_8$. Al, Fe^{III}, Fe^{II} and Mg can act as central atoms of the octahedron and add SiO_6 octahedrons by common adjacent pairs of O atoms forming silicato-salts; *e. g.*, muscovite, $[Al(SiO_4)_3]Al_2KH_2$. Amphiboles are considered polymerized pyroxenes which are unstable except in water-rich magmas and by loss of secondary SiO_2 groups form olivine: $\underset{\text{pyroxene}}{3[(SiO_2)_3.SiO_6]Mg_4} \rightleftharpoons \underset{\text{amphibole}}{[Mg((SiO_2)_3.SiO_6)_3]Mg_{11}} \rightleftharpoons \underset{\text{olivine}}{[Mg(SiO_6.SiO_2)_3]Mg_{11}} + 6SiO_2$. Tourmaline is formulated as $4[Al(SiO_4)_3]R_9 + 1\left[Al\begin{pmatrix}OBO\\O\\OBO\end{pmatrix}_3\right]Al_3$. Hydrolysis processes are discussed at length. A. R. MIDDLETON (C. A.)

10. **Prosiloxan, the silicon compound corresponding to formaldehyde.** A. STOCK. *Chem.-Ztg.*, **43**, 594 (1919).—HSiHO, prepd. by S. and C. Somieski by the action of water on SiH_2Cl_2, polymerizes rapidly to products similar to silicic acid; in the rapidity with which this occurs, and in its reducing properties, it is more active than HCHO. W. B. V. (C. A.)

11. **Prolonged action of carbonic acid on silicates and quartz.** C. MATIGNON AND (Mlle) MARCHAL. *Compt. rend.*, **170**, 1184–6 (1920).—Quartz, wollastonite, dioptase, mica, talc, asbestos, and glass, resp., in aq. suspension were submitted to the action of CO_2 under 10 atm. pressure for 10 years and 3 months. At the end of this time, all the *silicates* and the *quartz* itself were more or less *corroded*, and varying amts. of SiO_2 had passed into soln. Wollastonite showed the greatest signs of attack and the glass the least.

J. C. S. (C. A.)

12. **Study of transition points by a dilatometric method.** PAUL BRAESCO. *Ann. phys.* [9], **14**, 5–75 (1920); cf. *C. A.*, **14**, 876.—By a modification of Chevenard's differential method (*Rev. metal.*, **15**, (1917); cf. *C. A.*, **11**, 2743) giving the difference between the expansion of the sample and that of a standard substance, B. has detd. the temps. at which abrupt changes of vol. occur, the changes being due to changes of phase. For standard an alloy of Ni and Cr. (10 per cent Cr) was entirely suitable, as the expansion of the alloy shows no irregularities up to 1000° and as the transition point of Ni is much depressed (to —175°) by the 10 per cent Cr. Many of the materials being powders were made into compact form by compression and by the addition of 5 per cent of sodium silicate. The following results were found for SiO_2; amorphous silica by pptn. had no transition; quartz α changes to quartz β at 575°; cristobalite α to β at 235°; tridymite α to β at 110–115° and to γ at 145°; quartz and amorphous silica to cristobalite above 1400°; tridymite to cristobalite at 1600°; quartz to tridymite between 1300° and 1400°. Thus cristobalite is the stable form above 1600°, while below 1600° tridymite is stable and at low temps. quartz is the stable form. The mean coff. of expansion of quartz is 12×10^{-6} between 100° and 300°; 14×10^{-6} between

200° and 300°; and 21.3 × 10^{-6} between 300° and 500°. A study of *clays and clay constituents* showed the following: The expansion of mica is regular up to 900°; natural clays show a decided break in their expansion at temps. from 630° to 840°, depending on the particular clay; kaolinite, however, showed a max. expansion at 500°, which confirms the work of Wallach (*C. A.*, **7**, 3647), who attributes the effect to dehydration of $2SiO_2.Al_2O_3.3H_2O$. Numerous expts. with metals and alloys are also described.

JAMES M. BELL (C. A.)

13. **Bauxite as a pigment.** A. COBENZL. *Farben-Ztg.*, **25**, 20 (1919).—The *blue* color of *bauxite* is due to FeS in an easy oxidizable colloidal form, and the $Al(OH)_3$ itself takes no part in the production of the color. A similar color may be observed in $BaSO_4$ that has stood for a long time in moist packages. In this case the org. matter in the water has reduced a little sulfate to sulfide, which has then been attacked by the acid present in the sample, and the liberated H_2S has reacted with the Fe compds. present with the production of colloidal FeS. J. S. C. I. (C. A.)

14. **Bauxite as a pigment.** M. RAGG. *Farben-Ztg.*, **25**, 151 (1919); cf. *C. A.*, **14**, 636.—R. agrees with Cobenzl (preceding abst.), that the *blue* color of *bauxite* is due to colloidal FeS. The occurrence of blue bauxite indicates that the mineral is composed of the residues from the soln. of aluminous limestones which have become mixed with org. material of animal and vegetable origin. The decompn. of the latter has then produced the H_2S required for the production of the blue color. J. S. C. I. (C. A.)

15. **Perchloric acid as a dehydrating agent in the determination of silica.** H. H. WILLARD AND W. E. CAKE. *J. Am. Chem. Soc.*, **42**, 2208–12 (1920).—The dehydrate of $HClO_4$ boils at 203° and at this temp. is a powerful dehydrating agent. Results are given for the estn. of SiO_2 in metals and alloys, limestone and sol. silicates showing apparent errors of only a few tenths of a mg. ALBERT SALATHE (C. A.)

16. **An aid in the determination of silica.** S. R. SCHOLES. *Chem. Analyst* **29**, 22–3 (1920).—Add a small amt. of Me-orange to the acid liquid before evapn. This serves as an indicator to ensure acidity, and dyes the gelatinous solid as it seps. from the soln. Every particle becomes colored and is less likely to be lost. H. M. LANCASTER (C. A.)

17. **Opening up minerals with phosgene.** CHARLES BASKERVILLE. *Science*, **50**, 443 (1919).—An abstract. The bleaching of the ferruginous siliceous bricks by the action of phosgene in plants where the poisonous gas was manufd. has been noted. The useful application of this method of conversion of Fe oxides into volatile $FeCl_3$, with a bleaching, for glass-sand, was suggested by Hulett. Phosgene under the influence of heat is very reactive at temps. of 450° and above. B. has converted oxides at Al and Ce, insol. in acids, oxides of Zr and Th, insol. in acids except boiling concd. H_2SO_4, directly into water-sol. chlorides or oxy-chlorides. Bauxite and carborundum yield ferric

and Al chlorides. Zr chloride has been distd. from zircon (silicate), $FeCl_3$ from the contaminating Fe being fractioned away due to its greater volatility. The silica remains behind. Thorianite yields sol. Th and U chlorides. The procedure is very simple. The pulverized material is heated in a quartz tube in a stream of gaseous phosgene. (Cf. Washburn and Libman, THIS JOURNAL, 3, 635 (1920).) E. J. C. (C. A.)

18. **Catalog of Swedish geological, paleontological, petrographic, and mineralogical literature for 1907–1917.** FR. E. AHLANDER. *Geol. För. Förh.*, 41, 539–606 (1919).—A list of titles, names of authors and references for about 1000 papers, arranged alphabetically by authors, published in Sweden and elsewhere. Many are in English, and some are chem. in nature.

W. SEGERBLOM (C. A.)

19. **Chemical Composition of Post-Tertiary clay material.** O. TAMM. *Geol. För. Förh.*, 41, 462–8 (1919).—Analyses of clay from 4 different deposits in Sweden showed distinctly lower SiO_2 and higher Fe and Mg content than in the coarser layers. K. was often higher, Na lower, and Ca content variable. The Al content was always noticeably higher than the max. for the kaolinite formula, from 5 up to 12 per cent. W. S. (C. A.)

20. **The origin of Flint.** R. M. BRYDONE. *Geol. Mag.*, 57, 401–4 (1920).—There are 3 kinds of flint: separate, interstratified continuous lines, and contrastified continuous lines (veins). The origin of these is discussed, a penecontemporaneous origin being advocated for the first 2, and a later origin for the veins. S. G. GORDON (C. A.)

21. **Talc Mining in South Africa.** ANON. *Eng. Min. J.*, 110, 860.—A short résumé of a report by Trade Commissioner R. A. Lundquist in which production figures are given since the first production in 1913, and the various districts are very briefly described. The price of the crushed talc is given as £6, 5s. a ton and for uncrushed bulk talc as £3, 5s. f. o. b. Delago Bay.

22. **Bauxite and aluminum in 1919.** JAMES M. HILL. *Min. Res.*, 1919, Pt. I, 33–40.—During the year 1919 the production of bauxite in the United States fell off 38 per cent from that of the preceding year, the entire decrease being in the Arkansas production, since the other districts showed a slight increase. Considerable bauxite was imported from South America, while a small amount was exported to Canada. Of the total production of 376,566 long tons a little less than 10 per cent was used by abrasive manufacturers and 0.25 per cent for the making of refractories. This is a decrease of 70 per cent in the amount used for abrasives due to an overstock accumulated during the war. The price of bauxite ranged from \$5.45 to \$10.00 a long ton with an average of \$5.85 paid at the shipping point. Data are given on foreign production, with the exception of France, for the years 1915–1918. A list of bauxite consumers is given, also short descriptions of the principal districts in the United States and in foreign countries.

23. **Thorium, zirconium, and rare earth minerals in 1919.** WALDEMAR T. SCHALLER. *Min. Res.*, 1919, Pt. II, 1–32.—The present report is essentially a reprint of the report for 1916 with the data brought up to date as far as is possible. The two Zr minerals zircon and baddeleyite or brazilite are described. The former has a quite general distribution in pegmatites. The United States localities are N. C., Fla., Va., N. J. and Okla. Baddeleyite is found in commercial quantities only in Brazil. The extraction of Zr from zircon is so difficult that deposits of zircon are of little value so long as there are deposits of the oxide baddeleyite. In consequence of this there has been no production of zircon in the United States since 1911, the entire supply of Zr ore coming from Brazil, mainly in the form of the oxide. A possible use of the metal Zr is in the mfg. of alloys, with nickel or iron for machine tools. This utilization has not yet reached the commercial stage. Various other methods of using Zr have been suggested but at the present the chief use is as a refractory in the form of the oxide. A synopsis is given of the uses of Zr, also production figures for the years 1902 to 1916. Data are not available since the latter date. D. D. SMYTHE.

24. **The mining industry in North Carolina during 1913–1917.** JOSEPH HYDE PRATT AND MISS H. M. BERRY. *Econ. Paper* No. 49. N. C. Geol. and Econ. Survey. This paper gives a general survey of the mining and mineral industry of the state, only a portion of which is abs. here. *Abrasives.*—North Carolina is better supplied with corundum than any other state in the Union. Com. quan. are found only in 4 counties, though 60 localities are known. The production has been quite interrupted and, except for the year 1917, quite small. Garnet is mined but little, owing to the distance of the deposits from the railroad. Of that quantity some is used after being ground, while some is quarried massive and used for millstones. *Barite* occurs in a few localities and in 1917 was being mined by only three companies. The value of their product for that year was $5,080. *Talc.*—Deposits of this mineral occur in the western part of the state. Pyrophyllite is also mined and sold as talc but is inferior in quality to the true talc. Little of this talc is sold in the crude state, so no production figures are available except for the manufactured product. The yearly production for the last 20 yrs. has varied from about 2000 to 6,000 short tons. *Feldspar* was first produced in this state in 1911, at which time N. C. ranked 6th in quantity produced. The output steadily increased till in 1917 N. C. ranked first in quantity and second in value of feldspar produced. The feldspar is orthoclase or potash feldspar and is obtained from granite pegmatite dikes. Much of the product is ground at Erwin, Tenn., while the remainder goes to mills in O. and N. J. *Glass sand* has not been marketed from this state as yet, but there are deposits which could undoubtedly be used for this purpose. *Clays.*—With the exception of the kaolin, which is all shipped out of the state raw, most of the clays are manufd. before being placed on the market. The kaolin produced in 1917 had a value of $182,176 and the manufactured product for the same yr., mainly common brick, a value of $1,662,307. The results of a number of

tests of N. C. clays are given, also a short description of the value and uses of kaolin and other clays. D. D. SMYTHE.

25. **Graphite.** BENJAMIN L. MILLER. *Mineral Ind.*, 28, 314–28 (1919).—A review of the industry in the United States and foreign countries. A. B. (C. A.)

26. **Gypsum.** FRANK A. WILDER. *Mineral Ind.*, 28, 329–36 (1919).—Production and utilization are discussed. A. B. (C. A.)

27. **Magnesite.** SAMUEL H. DOLBEAR. *Mineral Ind*, 28, 433–41 (1919).—Production and trade in the United States and foreign countries are discussed, with bibliography. A. B. (C. A.)

28. **Mica.** J. VOLNEY LEWIS. *Mineral Ind.*, 28, 461 (1919).—A review, with statistics. A. B. (C. A.)

29. **Talc and soapstone.** FREDERICK B. PECK. *Mineral Ind.*, 28, 656–63 (1919).—Production and imports are given and the use discussed. A. B. (C. A.)

30. **Titanium and zirconium.** ANON. *Mineral Ind.*, 28, 685–7 (1919).—A review of the industries. A. B. (C. A.)

BOOKS

31. CLIBBENS, D. A.: **The Principles of the Phase Theory.** London: Macmillan & Co., Ltd. 382 pp. 25s. (C. A.)

Refractories and Furnaces

32. **Physical characteristics of specialized refractories. III. Electrical resistivity at high temperatures.** M. L. HARTMANN, A. P. SULLIVAN AND D. E. ALLEN. *Trans. Am. Electrochem. Soc.*, 38 (preprint) (1920); *Chem. Met. Eng.*, 23, 721 (1920).—Curves and data are given showing elec. resistivities of 9 commercial refractories at temps. up to 1500°. Results are necessarily only approx. CHARLES HECKER (C. A.)

33. **Fused silica; its properties and a few of its uses.** STEPHEN L. TYLER. *Trans. Am. Inst. Chem. Eng.*, 11, 189–202 (1918).—The history of development of this manuf. is given. The use of fused SiO_2 in cascade concentrators for H_2SO_4 is discussed. It is not suitable for H_3PO_4. Prospective development in spark-plug insulators is discussed. JAMES R. WITHROW (C. A.)

34. **Core baking in electrically heated ovens.** JESSE L. JONES. *Metal Ind.*, 18, 450–1 (1920).—Details of construction of the furnace and thermo-regulator, capable of holding within 5° any temp. between 150 and 1450°F are not given. Comparative tests were made between the electrically heated oven and others heated with gas or oil. The binder was a mixture of linseed and mineral oils with or without dextrin. The cores were baked at 300 to 450°F. The results obtained were in favor of the elec. furnace as follows: (1) Oven temp. uniform throughout; (2) temp. held steady within 5°; (3)

no annoyance from fuel combustion products; (4) cores well baked in one hour at 450°F; (5) cores 50 to 200 per cent stronger, when tested by compression; (6) cores may be baked much faster; (7) about 1 kw.-hr. of elec. power required for 12 lb. of green cores. J. O. HANDY (C. A.)

35. **The measurement of physical properties at high temperatures.** A. GEORGE TARRANT. *Trans. Farraday Soc.* **15**, Pt. 3, 83–97 (1920).—See *C. A.*, **14**, 1018. It was found that *breaks in the carbon spiral of an elec. resistance furnace* could be easily and completely repaired by heating the break by passing current and applying a mixt. of graphite and synthetic resin, which flowed into the hot crack and subsequently became carbonized. W. P. WHITE (C. A.)

36. **A laboratory high-temperature coke-resistance electric furnace.** W. F. MUNN. *Chem. Met. Eng.*, **23**, 345 (1920).—Temp. of over 1800° can be readily and quickly obtained. The max. temp., 2300°, was attained in 20 min. from a cold start. The furnace body is built of silocel brick, 9 × 2.5 × 4.5 in.; electrodes are 1 in. diam. graphite; and a graphite crucible 1.25 in. in diam. The space between the crucible and electrodes is filled with granular coke. The transformer has 8 sep. connecting taps, giving a range of 20.7 v. to 38 v., 65 to 120 amps. The cost of operation does not exceed 30 cts. per hr. with power at 10 cts. per kw.-hr. C. A. FLORTING (C. A.)

37. **Relative thermal economy of electric and fuel-fired furnaces.** E. F. COLLINS. *Gen. Elec. Rev.*, **23**, 768–73(1920).—C. gives an elaborate table of the power cost and per cent heat available for coke, oil, natural and city gas, anthracite, bituminous coal, and electricity, at 200, 875, 1250, and 1550°, *i. e.*, the usual temps. for baking heat-treating, forging, and melting. The thermal efficiency of a furnace decreases rapidly with rising temp., due to radiation losses, and also much more in the fuel-fired due to heating up of air for combustion, a 50 per cent excess over theoretical generally being required. Only large installations are designed to recover this heat from the flue gases. Since the cost of combustible fuels is rising more rapidly than elec. rates, the cost per B.t.u. is coming to favor the latter. But already the increased output and improvement in quality from elec. equipment have resulted in considerable reduction in manuf. costs. Examples of the rapidly increased use of elec. heating are ovens for baking cores, japan, and enamel, for annealing, hardening, and carbonizing, and furnaces for practically all brass melting. F. H. HOTCHKISS (C. A.)

38. **Recent developments in furnaces for solid fuels.** PRADEL. *Feuerungstechnik*, **9**, No. 2, 13–17 (Oct., 1920).—Review of German patents, with 10 figures. C. J. WEST (C. A.)

39. **Coal saving in the chemical industry.** DAVID BROWNLIE. *Chem. Trade J.*, **67**, 247–50, 311–4, 343–5 (1920).—A report of conclusions based on personal inspection of 60 typical steam-boiler plants of chemical industries of Great Britain. The av. net efficiency of the boiler plants in question is only

58 per cent; by reorganizing them along modern scientific lines it may be raised to 75 per cent with a consequent saving of 23 per cent in the coal bill. Faults pointed out are (1) improper design of grates; (2) ignorance of heating value of coal used; (3) lack of records of water evapn.; (4) improper treatment of feed water, with resultant scale troubles; (5) failure to use economizers, CO_2 recorders and superheaters. In addition chimney drafts and steam jets are used where mechanical draft should be employed, brick work and pipe covering are defective and firing is poor. As to the cause, "the chief engineer of many chemical plants is merely a glorified mechanic without scientific experience or education, paid and treated accordingly."

H. L. OLIN (C. A.)

40. **A new material for crucibles.** ANON. *Brit. Clayworker*, 29, 204 (1920). —The new bodies are made by adding bituminous or oil shale to clay. Other material containing volatile carbon which is decomposed upon heating may be used. Such a mixt. is embedded in oil shale or coke to maintain reducing conditions and baked at 700°–800°C. If the product is then fired to 1600° C it becomes hard and resist. to acids resembling carborundum and may be ground and used as an abrasive. Biscuit ware may be saturated with liquid hydrocarbons and fired under reducing conditions so as to produce a similar product. The material differs from plumbago crucibles, carbon bricks, etc., inasmuch as the clay is saturated with minute particles of carbon. These particles may be sealed in the clay by firing until the necessary degree of vitrification has been reached, and by this means they may be completely protected from being burned away. This latter is a serious defect in some articles mfgd. from carbonaceous matter and clay. H. G. SCHURECHT

BOOKS

41. HERMANN, HUGO: **Elemente der Feuerungskunde.** Leipzig: Otto Spamer. M. 11, bound M. 16. For review see *Chem. App.*, 7, 160 (1920).

(C. A.)

42. JÜPTNER, H. v.: **Beiträge zur Feuerungstechnik.** 1 Teil. Leipzig: Arthur Felix. 189 pp. M. 10. (C. A.)

43. THOMAS, H. H., HALLIMOND, A. F., AND BRADLEY, E. G.: **Special Reports of the Mineral Resources of Great Britain. Vol. XVI. Refractory Materials, etc., Petrography and Chemistry.** London: H. M. Stationery Office. 5s. (C.A.)

Whiteware and Porcelain

44. **Chemical stoneware.** A. MALINOVZSKY. *Trans. Am. Inst. Chem. Eng.*, 11, 103–18(1918).—The manuf. of chem. stoneware is a sep. and distinct branch of the ceramic industry which received great impetus in this country due to the war. Great care should be taken to produce a uniform body and skilled workmen are necessary. Lab. tests were made on the amt. of water absorbed, loss after being filled with 66° Bé. H_2SO_4 and boiled for 12 weeks and loss of wt. on treating powdered crucibles with nitric and sulfuric acids. The tests

showed less than 1 per cent absorption of water or loss of wt. Microscopic examns. have shown that in all cases, in the vitrified compn., the burning has produced enough fusion among the materials used in making the ware to develop a glass as in lavas. The very great importance of proper annealing is not understood by most manufacturers. Discussion by Whitaker says that it is very difficult to get proper resistance to acids, resistance to temp. changes and proper tensile strength of the burnt body combined in one piece of chem. stoneware, especially large pieces as compared to lab. size articles as discussed in this report. Tensile strength of the stoneware goes from 600 lbs. to a max. of over 2,000 pounds to the sq. in. Bebie remarked that European enameled ironware had an advantage over Am. material because the European material was enameled cast iron, whereas Am. is mostly enameled steel, which has more of a tendency to warp when exposed to changes in temp. whereby some of the enamel is chipped off. Malinovzsky states that if the stoneware body is attacked to the extent that it commences to dissolve 1.5 per cent the first half year, the dissolving action will increase more rapidly, with sometimes dangerous results to workmen. He also says that the success of the manuf. of chem. stoneware depends upon the material and its prepn., design and careful workmanship, and third on density, including strength. However, the strength is not proportional to the thickness. Failure is also produced in chem. stoneware by applying salt glaze. For surface protection feldspar glaze is best, it being under control and not attacked by alkalies or acids. JAMES R. WITHROW (C. A.)

45. **Manufacture of spark plugs.** ANON. *Clayworker*, 324–326 (1920).—The process used by the Champion Ignit. Co., at Flint, Mich., is described. 11 domestic clays are used in the mix. The mixt. is blundged, filter pressed and kneaded on a kneading table. A throwing mach. forces the clay through a small cylinder slightly larger than the plug, after which the plugs are baked in revolving ovens. The cylinders are then turned down to form seen in the finished Buick plugs. During the same operation the upper end of the insulator is threaded to take center wire. The forms are again sent to an oven where more moist. is driven off, after which they are glazed. The center wire is cut off in proper lengths and welded to the head that screws into the porcelain. The threads are then cemented and the center wire is screwed into place. The porcelain is again baked until cement is as hard as the porcelain. To insure against leaky plugs an asbestos gasket enclosed in a thin shell of copper is placed at the lower shoulder of the porcelain flange.

H. G. SCHURECHT

Glass

46. **Dissolved gases in glass.** EDWARD W. WASHBURN, FRANK F. FOOTITT AND ELMER N. BUNTING. Urbana, Ill. *Univ. of Ill. Eng. Expt. Sta. Bull.*, No. 118 (1921). The existence of dissolved gases in considerable quantity in a piece of perfectly clear barium flint optical glass was demonstrated by the method of "sudden evacuation." The glass was melted at atmos. pressure in

a vacuum furnace (figure). When the temp. reached about 1200°C the furnace was connected with a large evacuated tank. The furnace cooled under a pressure of less than 1 cm of mercury. On opening furnace most of the glass was found outside of the pot, in the form of a large white mass of foam (figure). The increase in volume of the mass was about 6 times that of the original piece. A special apparatus (figure) for both measuring and analyzing the dissolved gases was developed. The furnace consisted of a Pyrex glass tube 5 × 13 cm, with ground glass stopper, containing a porcelain melting pot wound with Pt wire. 25 or 50 g. of glass were introduced into the pot and after removal of adsorbed moisture the temp. was raised to 1400°C and maintained until manometer reading was steady. An Orsat app. was used to analyze the evolved gas for CO_2 and O_2 any residual gas being considered N_2. The accuracy of the chemical analysis was about 1 per cent. The three glasses investigated were; a barium flint optical, a light flint bulb, and a boro-silicate laboratory glass.

TABLE

	Volume per cent S. T. P.				Weight per cent				Concentration. Moles per liter		
Glass	O_2	CO_2	N_2	Total	O_2	CO_2	N_2	Total	O_2	CO_2	N_2
Barium-flint (1)	83	27	1	110	0.035	0.011		0.046	0.033	0.011	
(2)	36	12	1	48	.015	.0045		.020	.016		
Light-flint	4.5	10	3	18	.0045	.014	0.0025	.021	.004	.010	.0003
Boro-silicate	6	5	6	17	.0036	.0035	.0031	.010	.0028	.002	.0028
Water at 0°C									.0023	.080	.0010

The quantity and nature of the gases present in finished glass obviously depends upon the batch composition and the melting and finishing procedures. It is not probable that any appreciable quantities of gas are absorbed from the furnace atmos. except possibly in the case of glasses which are stirred mechanically for a long period. The authors hint at possible applications in the construction of high vacuum scientific apparatus and technical operations in machines using the vacuum gathering principle A vacuum furnace process for the manufacture of certain types of glass is possible on an industrial scale. It offers the advantages that the fining operation is eliminated, the finishing temp. reduced, and the product is free from even the smallest seeds. WM. M. CLARK.

BOOKS

47. SPRINGER, LUDWIG: Laboratoriumsbuch für die Glasindustrie. Verlag Halle, Wilhelm Knapp. 142 pp. M. 12, bound M. 14, 80 + 30 per cent. Verlagerzuschlag. For review see *Z. angew. Chem.*, **33**, II, 392 (1920). (C. A.)

Enamels

48. **The enameled steel insdutry.** WM. ZIMMERLI. *Trans. Am. Inst. Chem. Eng.*, **11**, 299–300 (1918).—Difficulties of the industry in war-time are discussed. JAMES R. WITHROW. (C. A.)

Cement, Lime and Plaster

49. **Thermal phenomena in the setting of portland cement.** F. Killig. *Concrete* (Mill Sec.), **17**, 120 (1920).—See *C. A.*, **14**, 3515.

J. A. Montgomery.

50. **Corrosion tests.** Anon. *Concrete* (Mill Sec.), **17**, 126 (1920).—An investigation carried on by the National Lime Association gave results which indicate that lime can be used to advantage in gypsum construction for the purpose of preventing the corrosion of reinforcing steel.

J. A. Montgomery.

51. **Action of alkali soils and waters on concrete.** A. S. Dawson. *J. Eng. Inst. Canada,* **3**, 476–80 (1920); *Eng. Cont.*, **54**, 388–9 (1920).—Soap and $Al_2(SO_4)_3$ afforded some protection to concrete against alkali; however, soap reduced the tensile strength somewhat. The mixing of cement with weak solns. of H_2SO_4, Na_2HPO_4, MgF_2 and $(COOH)_2$ has been shown by lab. tests to increase the alkali-resisting qualities of concrete. According to D., the effects of most of the alkalies have also been shown to be less pronounced on neat cement briquets than on sand cement briquets, and in a degree proportional to the amt. of sand. J. A. Montgomery.

52. **A contribution to the dispersoid and colloid chemistry of plaster. I.** Wo. Ostwald and P. Wolski. Leipsig. *Kolloid-Z.*, **27**, 78–92 (1920).—The older theory of the setting of plaster, which attributes the process to the interlocking of needle-like crystals of $CaSO_4.2H_2O$ deposited from a supersatd. soln., can not account fully for the facts. A number of investigators have suggested that colloidal phenomena play a part, but have not been able to study the question because of the lack of a suitable method for following the kinetics of setting experimentally. O. and W. find that the observation of the change in viscosity of dil. suspensions of plaster with time after prepg. affords the desired exptl. method. The detns. were made in an Ostwald type viscosimeter. The viscosity-time curves are S-shaped, the viscosity rising slowly at first, then more rapidly, and finally becoming const. at its max. value. The time required to reach the max. measures the time of setting of the plaster. The concn. of suspension suitable for these expts. lies between 2 and 5 per cent. The higher the temp. the lower the max. viscosity. In one case the max. viscosity at 0° was 350 units, at 18°, 110 and at 60°, 23. Freshly ground plaster gives a higher viscosity than the same plaster after standing a few days. The dispersity of the plaster has an enormous influence, the finer the particles the higher the max. viscosity of the suspension. Added substances have an important influence. KCl causes the max. viscosity to be reached more quickly, but at a lower value. NH_4Cl gives a lower max. viscosity. With acetic acid the max. is reached more slowly, but is at least as high as the suspension with no addition. Further work is in progress.

F. L. Browne, (C. A.)

Books

53. TEDESCO, N. DE, AND FORESTIER, V.: Nouveau manuel théorique et pratique du constructeur en ciment armé. 2nd Ed. Paris: Cg. Beranher. 316 pp. For review see *Chimie & industrie*, 4, 572 (1920). (C. A.)

54. **The use of volcanic slag in concrete to save cement.** H. SACHSE. *Tonind-Ztg.*, 44, 831–833 (1920).—C. Platzmann (*Zement*, 19, 227) used slag in the following proportions in concrete: 1 cement, ½ to 1 slag, and 4 to 11 silica. Also cement and fine sand mixtures were tested varying between the following limits: 1 cement and 7 to 11½ silica. The volcanic slag used had the following composition: SiO_2 56.4 per cent, Al_2O_3-Fe_2O_3 22.58 per cent, CaO 2.71 per cent, MgO 1.43, SO_3 trace, Na_2O-K_2O 77.94 per cent, Hygro. H_2O 2.83 per cent, Chem. H_2O 6.47 per cent. P. found that by using finely ground slag or sand together with cement the compress. strength is increased and less cement is required for concretes made with the same. Similar results can be obtained with finely ground brick dust or blast-furnace slag. By fine grinding, silicic acid is formed which combines with the free lime present in cements forming $CaSiO_3$. If no free lime is present, no bonding due to the silicic acid will result and the slag would tend to weaken the concrete since it would then simply act as an aggregate. S. suggests the addition of lime to cements together with finely ground slag thus obtaining the maximum bonding. H. G. SCHURECHT.

55. **Plaster of Paris as putty.** G. ATTERBERG. *Tonind.-Ztg.*, 44, 871 (1920).—During the war numerous cements have been used as a substitute for putty which requires linseed oil. Most of these, however, were unsatisfactory in that the chemicals in the cement attacked the hands of the user. Plaster of Paris may be used in the place of these by adding sufficient lime to render the plaster slow setting. H. G. SCHURECHT.

ACTIVITIES OF THE SOCIETY

Actions of the Board of Trustees

January 19. It was voted to authorize Dr. Washburn to purchase a typewriter, with stand, for the Editor's office.

January 19. It was voted to send the JOURNAL OF THE AMERICAN CERAMIC SOCIETY for 1921 to Dr. Rieki, Dr. Pukall, and Dr. Endell, of Germany, in exchange for such scientific investigations as they may desire to send for publication in the JOURNAL.

January 27. It was voted to increase the number of copies of the JOURNAL printed monthly from 2200 to 2500.

January 27. It was voted to increase the subscription rate of the JOURNAL OF THE AMERICAN CERAMIC SOCIETY from six dollars to eight dollars a year.

Meeting of the Pittsburgh District Section of the American Ceramic Society

December 1, 1920

The Pittsburgh District Section held its last meeting of the year at the Mellon Institute on December 21, 1920.

Chairman Peregrine called the meeting to order at 2.15 P.M.

The committee on nominations submitted its report and on motion, duly seconded, the secretary was instructed to cast a unanimous ballot for the following officers:

Chairman, J. Spotts MacDowell, Harbison-Walker Refractories Co., Pittsburgh, Pa.

Vice-Chairman, A. V. Bleininger, Homer Laughlin China Co., Newell, W. Va.

Secretary, J. W. Wright, Macbeth-Evans Glass Co., Charleroi, Pa.

Treasurer, Thomas H. Sant, John Sant and Sons Co., East Liverpool, Ohio.

Councilor, Francis W. Walker, Sr., Beaver Falls Art Tile Co., Beaver Falls, Pa.

The report of the treasurer was then submitted.

There being no further business the following papers were read:

"Properties of Commercial Gases," F. J. Denk, Consulting Mechanical, and Fuel Engineer, Pittsburgh, Pa.

"The Use of the Microscope in Ceramics," Dr. R. Thiessen, U. S. Bureau of Mines, Pittsburgh, Pa.

The paper by Mr. Denk prompted many questions of a practical nature from the members present. Dr. Thiessen presented the possibilities of the microscope in solving ceramic problems in a masterly way, and his paper interested all present.

C. C. VOGT, *Secretary.*

New Members received during January, 1921

Resident Associate

Anderson, John A., 299 Central St., Gardner, Mass., Central Oil and Gas Stove Co.

Bach, Julius H., 2647 Montrose Ave., Chicago, Ill., Bach Brick Company.

Bautz, Robert A., Murphysboro, Ill., Isco-Bautz Company, Inc.

Clark, Horace H., 325 Peoples Gas Bldg., Chicago, Ill., Fuel Engineer.

Dougherty, Robert H., National Lamp Works, Cleveland, Ohio, Assistant to Ceramic Engineer.

Grafton, C. V., Muncie, Ind., Treas. and Gen. Mgr., Muncie Clay Products Co.

Hail, Walter, Blackmer & Post Pipe Co., St. Louis, Mo.

Hart, L. H., 2800 Thirteenth St., N. W., Washington, D. C., Manager, Construction Dept., National Lime Association.

Kimberling, Henry P., Blackmer & Post Pipe Co., St. Louis, Mo.

King, Walter, A., Elyria Enameled Products Co., Elyria, Ohio, Assistant, Enamel Research Laboratory.

Manson, Mahlon E., Rundle Manufacturing Co., Milwaukee, Wis., Chemist.

Patten, D. M., Chattanooga Stamping and Enameling Co., Chattanooga, Tenn., Treasurer.

Reinecker, Haydn P., 145 Industrial Bldg., Bureau of Standards, Washington, D. C.

Shultz, J. Emmet, American Encaustic Tiling Co., Zanesville, Ohio, Modeler.

Turner, Eric W., Trenton Flint and Spar Company, Trenton, N. J.

Foreign Associate

Hawley, W. S., cr. George Howson & Sons, Ltd., Eastwood Sanitary Works, Hanley, Stoke-on-Trent, England, Managing Director.

Wang, C. Y., Rue de Paris, Extension, Hankow, China, Consulting Mining Engineer.

Corporation

Bach Brick Company, 2647 Montrose Ave., Chicago, Ill.

Chicago Crucible Company, 2525 Clybourn Ave., Chicago, Ill.

Russell Engineering Company, 1624 Railway Exchange Bldg., St. Louis, Mo.

Chicago Section

The ninth meeting of the Chicago Section of the American Ceramic Society was held at the City Club, 354 Plymouth Ct., February 5th, 1921.

The meeting was called to order by Mr. B. S. Radcliffe, chairman, with an attendance of 22.

After a delightful luncheon the following papers were read: "Notes on the Acid Resistance of Enameled Cooking Utensils" by B. T. Sweely. "Notes on the Manufacture of Lead Products Used in the Ceramic Industry" by Lester T. Wilson.

In the discussion on the first mentioned paper the cause of segregation of Borax or Boracic Acid in fritting enamels was brought up. In connection with Mr. Wilson's paper the fact was brought out that Lead Products used in the Ceramic Industry were purer than any other materials used.

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AMERICAN CERAMIC SOCIETY

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Papers and Program.—R. H. Minton, *Chairman*, General Ceramics Co., Metuchen, N. J., and the Chairman of the Industrial Divisions, the Secretaries of the Local Sections and the Secretary of the Society.

JOURNAL
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AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 4 **March, 1921** **No. 3**

EDITORIAL

PRACTICAL APPLICATION OUR PRESENT NEED

I do not wish to discourage any man or set of men from undertaking new discoveries or improvement methods, however slight the chance of adding greatly to present knowledge. Many dollars have been wasted in vain attempts to solve problems of which we are still ignorant but out of all such effort some progress will be made. Men who are willing to contribute of their means in efforts bearing but little promise of results are philanthropists. But nevertheless those who are engaged in the business for profit should be first persuaded to take advantage of what they now have.

The clay manufacturing industry is not so much in need of discovery as it is in need of grasping opportunity.

A recent editorial in a clay trade journal calls loudly for a reduction of costs by means of more technical investigation. In the same issue is an unanswered appeal from a subscriber for information as to how to remove lime pebbles from a common brick clay. On another page is the announcement of the departure from the industry of a prominent technical investigator. The three items answer pretty clearly the question "What's the matter with the brick industry?" A mania for technical information of no value unless it is applied. Inefficiency in the distribution of the most ordinary information. The departure from the industry of the very men and the only men capable of applying the information already available or to be yet acquired.

The first and foremost need of the clay industry is not so much

new technical information, as it is the ability and willingness to apply that which we already have. In other words, we need common sense engineering in the manufacture of brick and tile and a technically trained personnel on each individual plant instead of in a distant laboratory. The manufacture of brick and tile has, in the opinion of many, reached a critical point in its development. The public's need for such ware is undeniable but, in order to serve to the utmost, qualities must be improved and costs reduced.

Just as it would be extremely foolish to delay action until a steam launch were available to save a drowning man twenty feet from shore, with a row boat, a coil of rope and a life preserver right at hand, to say nothing of a half dozen good swimmers, so would it, in my opinion, be foolish to undertake an elaborate program of experiment like that involved in an experimental plant or an association laboratory and meanwhile make no attempt to get better results from present equipment or refuse to replace obsolete methods and equipment with that which is already available, and an obvious improvement and cost reducer. There are hundreds of hand fed dry pans, hundreds of dust bins that must be shoveled out. Hundreds of choking elevators too small for the work required. Thousands of steam and water leaks, miles of uninsulated steam lines, thousands of slide valve engines, scaly boilers and unpainted buildings, for none of which is the laboratory responsible or a curative. The spectacular, unusual saving is more attractive but in the clay industry, unfortunately, the spectacular things have never gotten anywhere and of the sponsors for the spectacular, revolutionizing plants which have been put across, we may say, like the knights of old "Their bones are dust. Their good swords rust. Their souls are with the saints we trust." But in their path is also rusting machinery and discouraged men.

The industry is essentially one of small investment and comparatively widely scattered units. Each plant, or at best, each district deals with a material and often a product peculiar to itself and each plant organization must develop an ability to apply good mechanical engineering and general ceramic information to the local situation. The common sense application of good

mechanics, sound construction and known ceramic technology can easily reduce the cost of clay ware manufacture twenty-five per cent.

In the matter of burning, for instance, why not shorten the burning time and get all the economy possible out of our present periodic kilns as well as experiment with other types. Each and every plant in the country can improve its burning by a more intelligent use of pyrometer, draft gauges, CO_2 recorders, or flue gas analysis. Many plants are using pyrometers, yes, but for what purposes? To regulate the burning? Not at all. They are in the office under lock and key and are used to discover if the night firemen sleep on the job. Draft gauges have been bought but, because of inability to use them to any advantage, have been discarded. Gas analyses have been made, during one burn, and no application made of the results.

I have visited some of the largest and some of the smallest clay working plants of the country, in sixteen different states, and I have yet to find a pyrometer, a draft gauge, an Orsatt apparatus or a CO_2 recorder on one and the same plant at the same time. I have never seen a hygrometer at work on any plant and only twice an anemometer, and I used both of them myself. I will venture the opinion that on more than half the plants of the country the above instruments could not be identified. Neither have I ever known a plant to buy its coal on a guaranteed heat unit basis, yet is has been established beyond question that fuel economy of any furnace depends upon the factors measured only by these instruments and the heating value of fuel depends upon the heat units it will produce.

Other consumers of large amounts of fuel find it profitable to employ men who are able to check up the fuel used and to get value for every dollar expended, why not the clay industry, which is the third largest consumer of coal and the greatest waster?

Another item of importance, not so easily corrected in present kilns, but possible of being cared for in future construction and possible of yielding a large return if cared for is the waste by radiation. Even clay manufacturers cover boilers and steam lines. Few other industries neglect it, but brick kilns exposed to wind, rain and zero temperatures are seldom insulated. Years

ago it was shown that the radiation losses of the average kiln is around twenty per cent. Aside from neglect to insulate, there is a serious loss due to pure shiftlessness. Kiln crowns during a burn are so hot that one can not walk upon them with comfort or safety to an ordinary shoe, but little attempt is made to stop the waste of heat. On many plants, if the crown holes are sufficiently covered to keep out most of the rain, to say nothing of keeping heat in, it is enough. On many plants it is the custom to light fires in a kiln being set when it rains to prevent the water from spoiling the ware. Can you expect to keep heat in a structure that won't keep water out?

Kiln repairs are often so neglected, especially on multiple stack kilns, that the draft through the kiln wall is stronger than through the flues and much of the developed heat never gets into the kiln at all.

With such management in the use of a simple, round, down draft kiln—and there are other abuses I have not mentioned—isn't it rather foolish to talk about spending $150,000 to $200,000 on an experimental tunnel kiln which, if installed on the average plant, would be subject to abuses and incompetence, instead of the intelligent handling it would require for successful operation.

I have in mind one continuous kiln which has never been a marked success but I was told in all seriousness that the burner changed the direction of the draft because a vine grows around a stump in that direction and he knew it would work better for that reason. I remember also a conversation with a paving brick manufacturer in which he stated that on a certain plant, so long as they kept a young fellow making gas analyses and watching the draft, they obtained wonderful fuel economy but, of course, could not keep him there all the time and the burners soon went back to the old methods. The question is WHY NOT KEEP THE YOUNG FELLOW THERE ALL THE TIME?

There have been many instances of loss incurred by adopting, without adapting, the processes and appliances of one plant by another. What each plant needs is the brain that can adapt. It can be had in the employment of technical men on the plants at salaries sufficient to keep them there. It can not be had any other way and each plant, in my judgment, can and must work

out its own salvation. It must put capital into brains and equipment instead of expense into common labor. Many operations can be carried on mechanically at very substantial savings. Transport of raw material, for instance, by man power and wheelbarrows should be stopped, whether the handling be ten feet or one hundred. The unloading of coal from railroad cars by hand shoveling and its distribution by wheelbarrow is another economic waste. But in a survey of some twenty odd plants in the Canton district within the past six months, I found but three using mechanical dry pan feeders and saw but one coal unloader. And with such conditions, we are asked to pile up technical information. May I ask WHAT FOR?

The results of any set of experiments can only be applied in a general way to conditions which are similar. Uniformity in a natural clay mixture is an utterly unattainable condition, even for any one given plant. Why not recognize this fact and stop talking about applying any given set of rules for die construction for instance, to the entire industry. Each new car of clay on every plant is more or less of a problem and an experiment. Who can tell whether it will grind, screen, pug, form, dry, burn or ship in any way similar to the last car mined. I admit this is extreme, but I recall a paper read in New York four years ago in which the entirely different characteristics of the chemical composition as disclosed by the microscope of two samples of paving block were very carefully described. The author stated that the two slides in question were taken one-fourth inch apart from the same paving block. For men to talk seriously of standardizing such materials in an experimental plant or anywhere else sounds rather foolish, doesn't it?

Lamination is a favorite subject for study. Two types are recognized—auger and die. To standardize the auger or the die on an experimental plant would mean to meet on that plant the varying clay and the varying workmanship of every plant in the country. It is a big job on any one plant, to say nothing of a hundred. I know of experiments extending over a period of nearly four years undertaken for the purpose of perfecting a die to run a column one inch thick and six inches wide, which was finally run with fair success. The same type of die was lately

used to run a column $1^1/_2$ inches thick and nine inches wide and it failed to the tune of more than ten thousand dollars but responsibility for the failure was placed on the burner, who is the favorite goat for a great many unexplained losses.

I have seen both hollow ware and brick columns run perfectly for ten, twenty, perhaps a hundred feet, then suddenly rag on one, two, three or four corners, run ragged for a few feet, heal, and go on again perfectly. What caused it? Nobody knows. Can you hope to eliminate, in an experimental plant, all the variables that might have caused it, so that you can furnish even one other plant one die that, without adjustment, positively will not rag a corner or show lamination from the time it goes on the machine until it comes off? If that can not be done in the experimental plant, then, so far as dies are concerned, it would be a failure and a positive waste of money. Better put a man at the machine of the average plant who has the brain and training to think—a technical man, if you will, who can design, balance and lubricate a new die for that particular material with as little lost time as possible. His results will be more positive after three months observation of a particular plant's material, equipment and personnel, than those of the experimental plant in a central location could possibly be in five years. It can not be hoped to put all machinery manufacturers but one out of business, neither can it be hoped to persuade the others that any one's design of machine is best, and all dies, all augers and all plungers laminate to a greater or less degree and all clays laminate to a greater or less degree when moved through a die by pressure. It is immaterial how that pressure is exerted, whether by auger or plunger. If the slippage of the clay particles over one another does not form bridges and gaps in the structure, the lamination may not be visible. Few plants but suffer from extreme lamination at intervals and few escape making a practically perfect product occasionally, but if the variable which brings about either of the above conditions on any individual plant can not be positively spotted in from ten to twenty-five years operation, how can one hope to locate it in an experimental plant, using perhaps enough of each of several kinds of raw material to run at capacity for half a day—or as any other plant, on a particular material, continuously.

If standardized on a given material, the plant would be worth to the industry just what Tom Jones or Bill Smith's plant is worth. It would have in it expert men in each department who could be hired away and who would run the same chance of failure on a new material that Tom or Bill's men now run. New men would have to be trained just as they have to be in Tom's plant or yours.

Each process on the average plant is subject to improvement, simple improvements too and not involving heavy outlays. Going back for a moment to the mechanical dry pan feeder, a device that has been on the market about three years. Many plants are still dumping material crushed or otherwise on to a floor in front of the dry pans to be shoveled into the pans by one or more men, depending upon the distance and amount. By the use of a feeder the shoveling is eliminated and more than one man for half a dozen pans could not possibly be kept busy.

Coal unloaders are not expensive to install or to operate, and if it is good business to unload fifty tons of coal a day by hand shovel, why would it not be good business to throw away the engine or motor and put enough laborers in a tread mill or on a crank to run the whole plant that way? MARION W. BLAIR.

TO AUTHORS OF PAPERS

The attention of authors of papers intended for publication in the JOURNAL is directed to the new regulations governing the preparation of author's abstracts, appearing on page 257 of this number. All manuscripts submitted to the JOURNAL should in future be accompanied by an abstract prepared in accordance with the directions given.

A STUDY OF THE HEATING AND COOLING CURVES OF JAPANESE KAOLINITE

By S. Satoh

ABSTRACT

Effect of heating Japanese kaolinite at 100° to 1400° C for 3 to 4 hours.—Ignition loss of weight was found to occur chiefly between 400° and 600°C, the rate of increase per degree reaching a maximum at about 460°C. Changes of microstructure were observed at 600°, 900–1000°, 1250–1300° and at 1400°C, when sillimanite began to develop.

Heating and cooling curves for Japanese kaolinite, to 1400°C.—A differential method was used with quartz sand as the comparison substance. In addition to the known reactions: (1) an endothermic from 450° to 700°, and (2) an exothermic near 950°, (3) an exothermic change between 1200° and 1300° was discovered, and it was observed that the endothermic reaction seems to include two periods of heat absorption, (la) 450° to 650° and (lb) 650° to 700°. **In explanation,** the author suggests that la is due to dehydration, lb to dissociation of kaolinite into free alumina and free silica, 2 to a polymerization of the alumia and 3 to the formation of amorphous sillimanite. In the discussion, E. W. Washburn calls attention to the fact that the author has neglected the endothermic reaction of quartz at 575°C and suggests that some of his conclusions are therefore erroneous.

Heating and cooling curves for alumina obtained from the nitrate, hydroxide and sulfate by calcination are given in figure 6. Exothermic reactions which are ascribed by the author to polymerization of alumia occur at 800° to 900° and at 1100° to 1200° instead of at 950° and at 1250° as in the case of kaolinite.

1. **Introduction.**—The endothermal and the exothermal reactions shown by kaolinite on heating have been examined by Le Chatelier,[1] Ashley,[2] Rieke,[3] Brown and Montgomery,[4] and Mellor and Holdcroft.[5]

While the details of the experiments carried out by these different investigators varied somewhat, the aim of all was to find the temperature of, and the range of, dehydration.

[1] *Bull. Soc. Min.*, **10**, 307 (1887).

[2] *Jour. Ind. Eng. Chem.*, **3**, 91 (1910).

[3] *Sprechsaal*, **44**, 637 (1916).

[4] U. S. Bur. Stand., *Tech. Pap.* No. **21**, (1913).

[5] *Trans. Eng. Ceram. Soc.*, **9**, 94 (1911); also **10**, 169 (1912).

Mellor and Holdcroft furthermore from their results concluded that Groth's[1] formula for kaolinite was probably the correct one, although several others have been suggested.[2]

In the present paper the writer presents the results of a study by a more accurate method, of the thermal changes produced in Japanese kaolinite, including a microscopic study of the change in structure on heating. The results are made public by permission of the Tokyo Electric Company, Ltd.

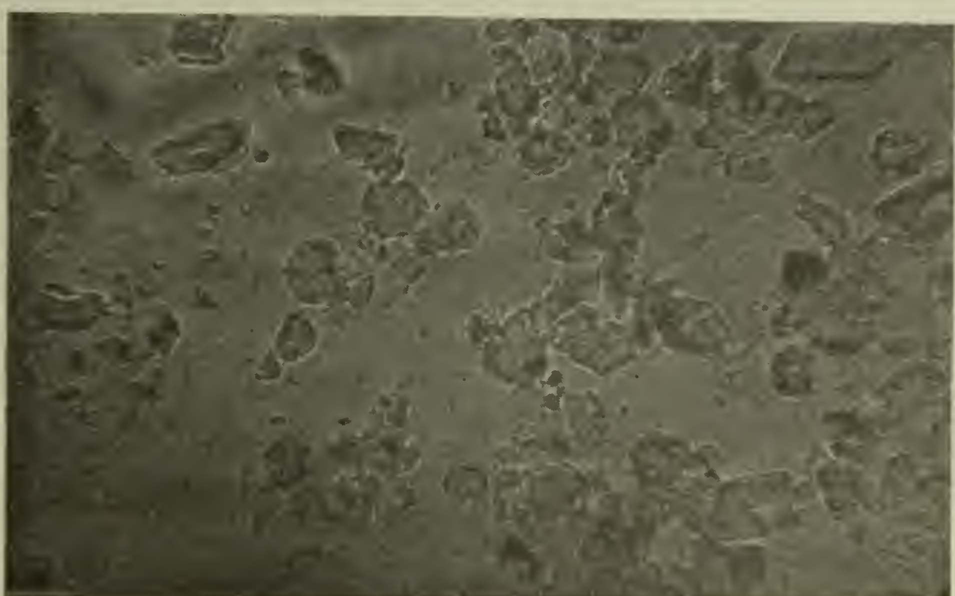


FIG. 1.—Unburned kaolinite from Azushiomura, Japan. Mag. 340.

2. **Chemical Analysis and Microscopical Observation.**—Crystalline kaolinite is rare in Japan, but recently a small quantity of it, obtained at Azushiomura in Fukushima province, was kindly given me for study by Mr. I. Asai, lecturer in the Tokyo Higher Technical School. A chemical analysis made in the laboratory of the Tokyo Electric Company, Ltd. is as follows:

[1] *Tabellarische Uebersicht der Mineralien*, 1898, p. 137.,

[2] Vernadsky, *Z. Kryst. u. Min.*, 34, 37 (1901); Haushofer, *Die Constitution der Naturalien*, p. 26, Braunschweig, 1874; Hundeshagen, *Z. angew. Chem.*, 21, 2454 (1908); Siemond, *Trans. Chem. Soc.*, 83, 1449 (1903); Clarke, U. S. Geol. Surv., *Bull.* 125, p. 32, (1895); W. and D. Asch, *Die Silicate in chemischer und technischer Beziehung.*

	Per cent		Per cent
SiO_2	45.01	MgO	trace
Al_2O_3	41.18	Alkali Oxides	0.86
Fe_2O_3	0.30	Loss on ignition	12.22
CaO	.72		

Microscopical examination showed that the sample, though contaminated with foreign materials, contains hexagonal plate like crystals (Fig. 1) which are undoubtedly kaolinite.

The material was heated for 4 hours in an electric furnace at each of the following temperatures, *i. e.*, 110°, 200°, 300°,

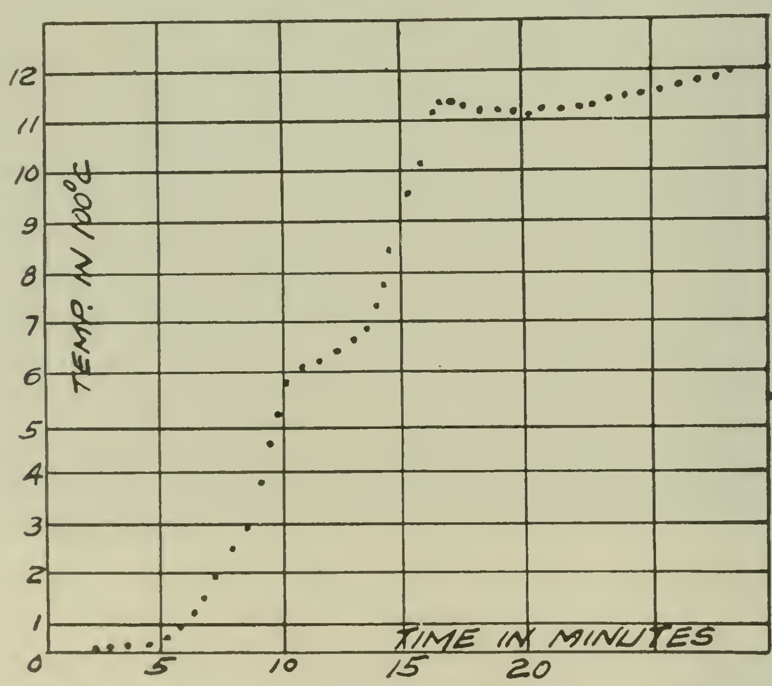


FIG. 2—Heating curve of kaolinite. After Mellor and Holdcroft.

400°, 500°, 600°, 700°, 800°, 900°, 1000°, 1050°, 1100°, 1150°, 1200°, 1250°, 1300°, 1350°, and 1400°C, its change of structure being examined microscopically after each heating.

The temperature of the electric furnace was measured with a precision voltmeter and a thermocouple, using a copper-constantan junction for low temperatures, and a platinum-platinum rhodium junction for high temperatures. At the lower temperatures the kaolinite tested showed many minute particles optically anisotropic. Each individual crystal gradually cracks

and shows a loss in transparency with rising temperature. A molecular disturbance first takes place near 600°C, and another between 900° and 1000°C. After the second disturbance, the material appears to be isotropic. It was furthermore noticed that between 1250° and 1300°C, the texture becomes granular and the grains appear to have a higher reflecting power. Sillimanite begins to develop near 1400°C. It seems that the structural change between 1250°–1300°C is common to all fire-clays, and without it sillimanite crystals are never developed.

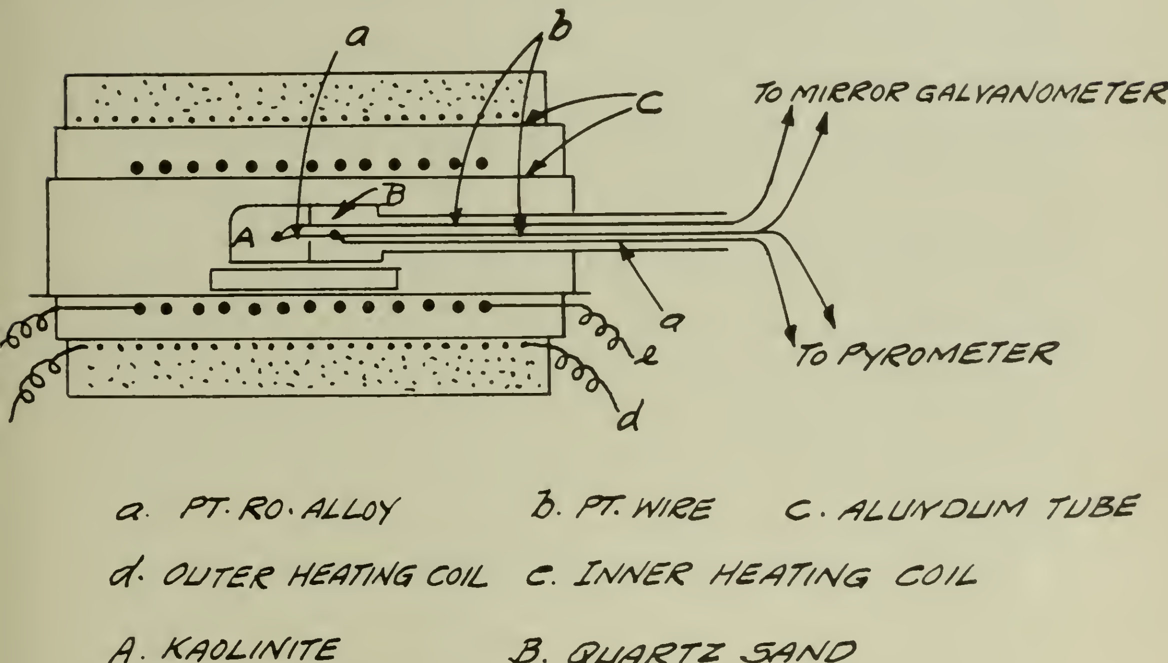


FIG. 3—Diagram of furnace and thermocouple set-up.

3. **Endothermal and Exothermal Reactions.**—To test these characteristics, I used at first the method employed by Mellor and Holdcroft, and obtained a heating curve, resembling theirs, which is shown in figure 2. The temperature at which the endo- and exothermal changes took place was rather indefinite and so I finally used the differential method, illustrated in figure 3. The apparatus consisted of a hollow cylinder of highly refractory material, 1 inch long and 1/2 inch in diameter, which was divided into two chambers, A and B, by a wall in the middle.

The differential thermo junctions were placed in the middle

of the tube, one in front of the wall and the other behind it. The differential junctions were so constructed, that two long pieces of platinum wire were connected by a short piece of platinum-rhodium wire, *a*. These two joints were placed exactly in the middle part of chambers A and B, and the other ends of the platinum wires were led to a glavanometer of Siemens and Halske make. In addition a long platinum-rhodium wire was forked from one of the joints to form an ordinary thermocouple with one of the platinum arms of the differential junction. The ends of this thermocouple were connected with a millivoltmeter

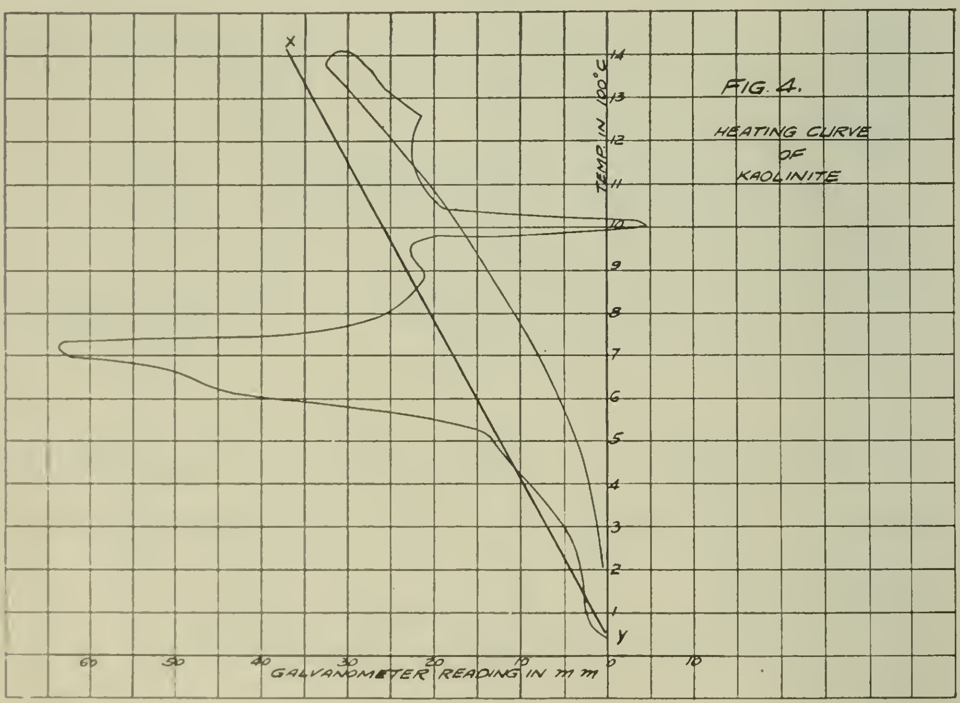


Fig. 4.

attached to a Siemen and Halske pyrometer. The chamber, A, was packed with Kaolinite powder, and the chamber, B, filled with calcined quartz sand. The temperature difference between the kaolinite and the quartz sand was observed with a mirror galvanometer connected to the differential junction; while the temperature of the quartz sand was simultaneously measured with the pyrometer. The sensitiveness of the differential thermojunctions was first determined and found to be 2 mm. scale divisions per degree of temperature.

Figure 4 represents the heating curve obtained by this method, the deflection of the mirror galvanometer and the temperature of the quartz sand being taken as the coördinates. The curve deviates as a whole to the left side of the ordinate axis, due to the slight deviation from the true position where the refractory cylinder ought to be placed in the furnace. Evidently the curve shows that the temperature rises more quickly at B than at A (figure 3), the rate being represented by the line *xy* (figure 4) although there is no change in the specimen. The cylinder was always placed as nearly as possible in exactly the same position in the furnace but in spite of this precaution, it occasionally happened that the zero line fell to the right side of the axis. In other words, the curve parallels the line *xy*, whenever there is no change in the specimen, and for this reason the line *xy* will be called the "zero line."

There seems no doubt that some endothermal change is taking place in the specimen, whenever any point on the curve lies to the left of the zero line, and has a tangent at that point which makes some positive angle with the zero line. The angle will be designated as positive, if a line makes an angle in the counter clockwise direction from the zero line: On the other hand some exothermal change is taking place when the point in the curve lies to the right of the zero line, so that the tangent at that point makes a negative angle with the zero line according to the above convention. It is difficult to calculate the quantities of heat absorbed or generated from this curve alone for these exist many complicated factors affecting the physical condition of the specimen, such as heat conduction, the difference in the specific heat of the specimens, and that of the surrounding material, etc., but, it is easier to determine the temperature of the endo- or exothermal reactions, from this type of curve than from that previously obtained by many other investigators.

A study of the curve given in figure 4 shows that there was heat absorption in the specimen up to 100°C followed by a faint evolution of heat up to 300°C. From 450° to 700°C there was a remarkable heat absorption, which corresponds to the range of dehydration and dissociation defined by Mellor and others. Considering this heat absorption in more detail

we see that the tangent to the curve makes a positive angle with the zero line above 450°C, its value increasing rapidly; after reaching a maximum at 600°C it decreases up to 650°C, while above 650°C it again increases up to 700°C. It is therefore clear, that there are two distinct periods of heat absorption, one of which ranges from 450°C to 650°C, the other from 650° to 700°C. An exothermal reaction is distinctly seen near 950°C, and another faint evolution of heat takes place between 1200°C and 1300°C. This exothermal reaction has not been noticed by other investigators.

The reactions mentioned above may be summarized as follows:

1. Heat absorption up to 100°C.
2. Weak heat evolution from 100°C to 300°C.
3. Heat absorption from 450°C to 650°C.
4. Heat absorption from 650°C to 700°C.
5. Heat evolution near 950°C.
6. Heat evolution between 1200° and 1300°C.

In this experiment, the error of temperature measurement did not exceed 30°C. The fact that the tangent to the curve makes a negative angle with the zero line means that although the temperature-difference between kaolinite and quartz is increasing positively, it is not certain that the specimen is undergoing some exothermal change. In the same way the fact that the tangent to the curve makes a positive angle with the zero line, does not definitely mean that the specimen is absorbing heat. Because, if a temperature difference is once found between the specimen and the quartz sand as the result of the endo- and exothermal reactions, and afterward the reaction ceases, it is natural that by thermal conduction the temperatures of the two parts tend to equalize, and as a natural consequence the above phenomena will take place.

4. **Discussion of the Results.**—The heating curve represented in figure 4 is the most typical one of the results obtained from many experiments. We repeated many times the same experiments with the same substance, and sometimes raised the temperature of the specimen 1400°C within the comparatively short period of $1^1/_2$ hours, while at other times it took 6 hours to reach the same temperature. The results show that, without

regard to the period of heating, the heating curve was always of the same type, and the transition points of the specimen did not differ by more than 30°C.

In the heating curve (see Fig. 4), the heat absorption at the outset seems to be caused by the evaporation of the moisture contained in the specimen, as it takes place at 160°C. The second heat evolution near 350°C may be caused by the oxidatión of the foreign minerals, which are easily oxidized, and the organic substances in the specimen. The third remarkable heat absorption is to be ascribed to the expulsion of the water of constitution.

The same kaolinite was heated 3 hours at a constant temperature in an electric resistance furnace, and the ignition loss at each temperature was measured. The results are represented on the following table:

Temperature	Ignition loss in per cent	Rate of ignition loss	Temperature	Ignition loss in per cent	Rate of ignition loss
200°C	0.43	0.28×10^{-2}	600°C	9.81	1.27×10^{-2}
300°C	.70	$.35 \times 10^{-2}$	650°C	10.45	0.49×10^{-2}
400°C	1.06	1.82×10^{-2}	700°C	.66	$.24 \times 10^{-2}$
450°C	.97	6.72×10^{-2}	750°C	.78	$.19 \times 10^{-2}$
500°C	5.33	$.13 \times 10^{-2}$	800°C	.84	....
550°C	8.39	2.84×10^{-2}			

The rate column in the above table shows the ignition loss per one degree of temperature-rise at the corresponding temperature. The results are also plotted in figure 5, A and B. Curve A represents the relation between the firing temperature and the ignition loss; curve B represents the relation between the firing temperature and the rate of ignition loss per 1°C, the tangent curve of curve A. The ignition loss represents, probably the loss of the water of constitution in the case of comparatively pure kaolinite.

Let us consider once more the third heat absorption, which starts from 450°C and ends near 650°C; the feature of the curve agrees exactly with that of the curve B in figure 5. It may therefore be supposed that the endothermal reaction between 450°C and 650°C may be ascribed to the expulsion of water. Moreover, this fact means that the heat absorption from 650°C

to 700°C would be produced by another cause than the dehydration; because it is absurd to assume that the heat absorption is again increasing after 650°C, for the rate of ignition loss at that temperature has already diminished to 2×10^{-2} per cent as seen in figure 5 B, and apparently there is no sign of increase in the rate. We can not definitely state the true cause of the endothermal reaction from 650°C to 700°C, but it seems probable that the kaolinite breaks up into free allumina and free silica above 650°C, while Mellor and Holdcroft thought the dissociation took place in the neighborhood of 500°C. If we carefully examine the results of their experiments on density, hygroscopicity and solubility in acid, the characters of kaolinite above 650°C, but not from 500°C, seem to coincide with those of alumina obtained by the calcination of aluminum nitrate. The inconsistency of the above supposition as regards the nature of the substances at the temperature below 650°C will be briefly discussed later. The change may be expressed by means of chemical symbols, in the following manner:

$$H_4Si_2Al_2O_9 \longrightarrow Si_2Al_2O_7 + 2H_2O \text{ at } 500°C$$
$$\text{and } Si_2Al_2O_7 \longrightarrow Al_2O_3 + 2SiO_2 \qquad \text{at } 650°C$$

It may be supposed from figure 5, A, that the OH group in kaolinite must be combined symmetrically with aluminium atoms or with silicon atoms.

The fifth exothermal reaction took place near 950°C. As it is difficult to determine by the old method the beginning of the reaction, several different temperatures have been found by previous investigators; Le Chatelier and Ashley assumed the point to be at 925°C. Mellor and Holdcroft compared the behavior of kaolinite with that of alumina prepared from aluminum nitrate, and allowing for the lag between material change and pyrometer indication, supposed that the exothermal change might happen at the temperature of 800°C, and that the alumina already dissociated from kaolinite at 500°C became polymerized at that temperature.

From our experiments, however, it seems probable that kaolinite, or its decomposition product, should change at somewhere near 950°C, and, as a consequence, heat evolution would take place. As mentioned above, there is not so much error in our

estimation of this temperature. On the other hand we observed from microscopical study that the optical properties of kaolinite change between 900 °C and 1000 °C.

5. **The Polymerization of Alumina.**—Figure 6 represents the heating curves of alumina obtained by the calcination of several aluminum salts, and figure 4 is included for convenient comparison. The alumina prepared by calcining aluminium nitrate for three

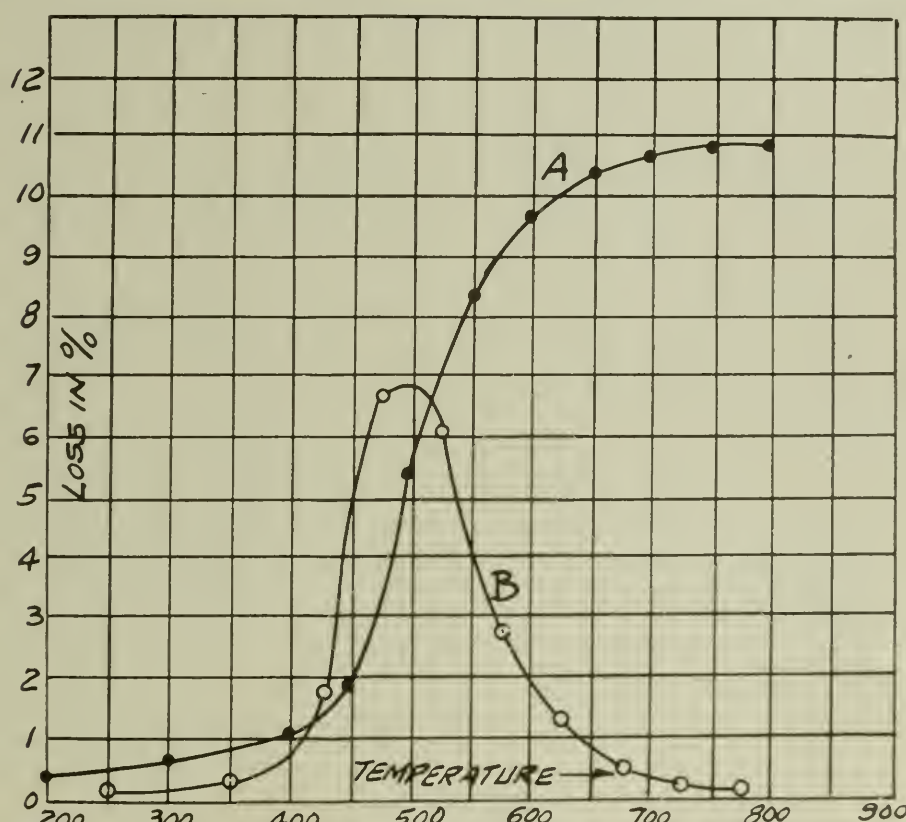


FIG. 5.—Loss in weight of kaolinite.

hours at 400 °C (curve B) has two exothermal changes near 800 °C and 1100 °C. The alumnia obtained by heating the aluminium hydroxide prepared from aluminum alum shows a remarkable heat evolution near 1150 °C (see curve C.). Calcined aluminium sulphate (see curve D) shows a remarkable heat absorption, which begins at 600 °C and turns suddenly to heat evolution near 900 °C; it shows another heat evolution near 1200 °C. Thus we could not find the exothermal reaction

corresponding to that of kaolinite near 950°C in the curves of these samples of alumina. Nevertheless if we remember that with the free silica and with the free alumina produced by the dissociation of kaolinite, the molecules of the former were interposed between those of the latter, it is possible that the polymerization of the alumina at 800°C might be held back until 950°C; and for the same reason the exothermal change which happens at near 1100°C would be retarded to the same degree, and the exothermal changes of kaolinite near 950°C and 1250°

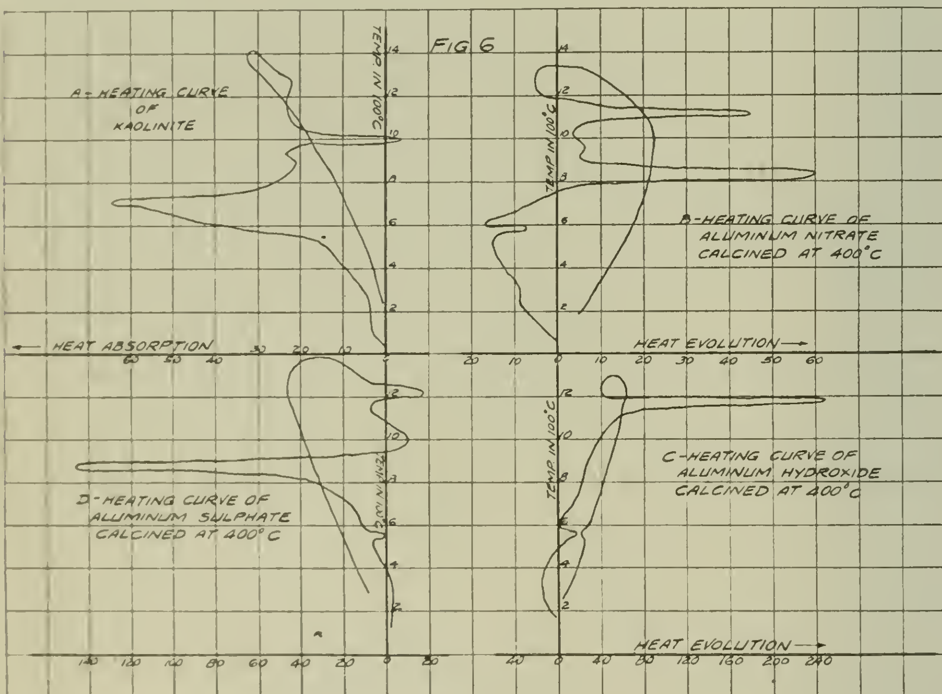


Fig. 6.

C should therefore be explained as the polymerization of the alumina dissociated at lower temperatures. Such an explanation of the thermal changes would be favorable to the dissociation theory.

On the other hand, we know from microscopical observations, that kaolinite changes to an isotropic condition above 900°C, and its structure becomes granular and more refractive at a temperature between 1200°C and 1300°C. The former transformation may be taken as the polymerization of the alumina, and the latter as the formation of amorphous sillimanite by the recombination of dissociated free alumina and free silica.

The fact that curves A, B, and D of figure 6 show in common a weak exothermal change between 500° and 600°C, and that this change does not appear in the heating curve of kaolinite, confirms the hypothesis that kaolinite does not dissociate at temperatures below 600°C.

At any rate, the fact that at temperatures over 800°C there is no heat absorption, makes it difficult to explain the formation of sillimanite according to the anhydride theory for without the decomposition of the anhydride kaolinite, sillimanite could not be formed.

The graphical formula of kaolinite is not of great importance at present; but if we assume the formula of Groth as

$$\begin{array}{l} (OH)_2 = Al - O - Si = O \\ \qquad\qquad\qquad\qquad\quad \rangle O \\ (OH)_2 = Al - O - Si = O \end{array}$$

we do not encounter any difficulty in explaining the properties of kaolinite, and there is no necessity of assuming a more complicated formula.

It should be added that neither endothermal nor exothermal changes appeared in the heating curve of the quartz sand tested. It is the writer's intention to carry on similar experiments on many clay substances and chemicals.

In conclusion, I wish to express my hearty thanks to Mr. I. Asai who supplied the kaolinite for study, and to Messrs. Amada and Murai, of our laboratory, who carried out the experiments with real care and zeal.

DISCUSSION

E. W. Washburn: A careful study of the heating and cooling curves of typical clays by the differential method is highly desirable. In the present investigation the author has, however, made an unfortunate choice of a comparison substance, since quartz on heating undergoes an endothermal reaction at about 575°, changing from the α- to the β-form. The influence of this reaction is evident in all of the author's curves where points have been taken in this temperature region. The reaction is a reversible one, and its occurrence should appear both on the heating and on the cooling curve as shown in the author's figure 6 C, which

is the only figure in which both the heating and cooling curves contain observed points in the temperature region in question.

The author has interpreted the effect due to this change in the quartz in terms of some supposed change in his other material which leads him to a number of erroneous conclusions.

It would seem desirable in experiments of this character to subject the sample to a preliminary low temperature oxidation in pure oxygen (or ozone?), followed by the removal of adsorbed moisture by means of a high vacuum at low temperature.

THE EFFECT OF THE REPLACEMENT OF FREE SILICA BY ALUMINA AND ZIRCONIA IN ELECTRICAL PORCELAIN[1]

By Robert Twells, Jr., and C. C. Lin

ABSTRACT

Effect on electrical porcelain of the replacement of free silica by alumina and zirconia.—Since it had been suggested that free silica may be detrimental to the mechanical and the dielectric strengths of electrical porcelain, a series of sixteen batches was prepared in which various proportions of the free silica were replaced, weight for weight, by alumina, zirconia or combinations of both, and bars and disks, after burning at cone $8^1/_2$ to 9 or at cone 12, were tested for **shrinkage, transverse strength, impact strength, heat resistance, absorption of moisture and dye penetration.** The results show that resistance to sudden temperature changes can be greatly improved by substituting zirconia,—that the danger of overburning can be greatly decreased by substituting alumina and that the mechanical strengths can be increased by substituting either or both; but in the case of dielectric strength, no improvement was obtained by substituting for the free silica.

Object of the Investigation

It has been repeatedly stated by different investigators that the presence of free silica in an electrical porcelain body is a disadvantage. The actual harmfulness of the free silica seems to be difficult to prove. It seems necessary that there be some kind of a very refractory substance, not easily attacked by fluxes present in any vitrified body to act as a skeleton structure and thus prevent warpage. The statements of most writers on the subject seem to be based on the well-known isomorphous inversions of quartz. These inversions cause volume changes which undoubtedly set up strains in the body during its cooling period and which leave the body in a state of strain even after the insulator is in use. In Part III, Report 53 of the National Advisory Committee for Areonautics, Bleininger makes the statement "volume changes are unavoidable in all porcelains containing free quartz in all amounts, due to the inversions noted. In a good spark-plug porcelain, the quartz should be eliminated from

[1] Received Feb. 7, 1921.

the compound, and replaced by a substance not subject to these inversions."

Treischel,[1] however has advanced the theory that the dielectric failure of porcelains apparently free from mechanical defects was due chiefly to the piezo-electric effect of the free quartz in the porcelain. This theory seems to be a possible explanation of the dielectric failure of porcelains which can hardly be ascribed to the inversions of quartz.

In view of these objections to free silica, it seemed well to try the effect of substituting various refractory oxides for flint in an electrical porcelain body. In this way it was hoped to obtain a refractory skeleton which would prevent warpage in the body, but which would not show the defects ascribed to quartz.

Method of Attack

It was decided to replace the flint with ZrO_2 and Al_2O_3 as being the two oxides which, from their use in other bodies, seemed most suitable for this work. The next question seemed to be whether to make the substitution directly pound for pound or molecularly. Any attempt to introduce the ZrO_2 and Al_2O_3 in the standard body by use of its molecular formula leads at once to difficulties. It is self-evident that it would cause great changes in the molecular formula of the body to replace the free silica with alumina. Such a change in the molecular formula would be much greater than the corresponding change in the body since the alumina would not actually become dissolved in the eutectic melt surrounding it. The substitution of the ZrO_2 for the free SiO_2 would not produce such a radical change in the body formula since both compounds take the form RO_2.

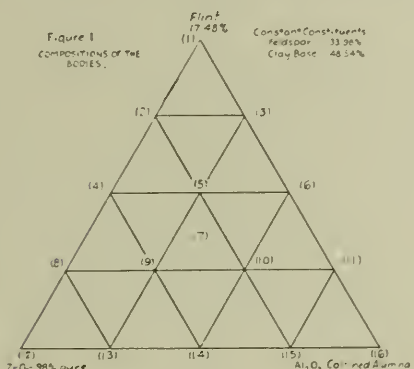
If we wish to assume that the ZrO_2 and Al_2O_3 will not be attacked by the eutectic melt surrounding them to a much greater extent than would the free silica, it seems logical to introduce them pound for pound to replace the latter. In this way the same amount of skeleton structure is introduced in each case.

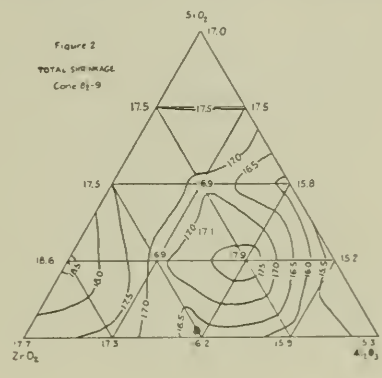
For the above reasons a simple triaxial substitution pound for pound was considered best. This is shown in figure 1.

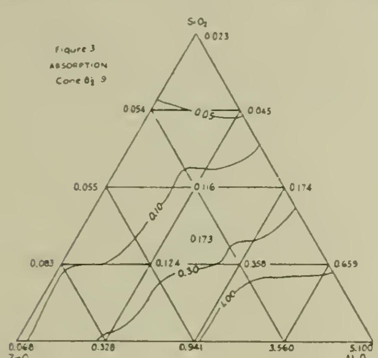
[1] Treischel, This Journal, **2**, 96(1919).

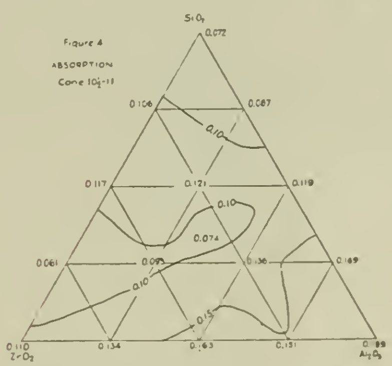
Preparation of the Bodies

A ten kilogram batch of each corner member was prepared, blunged for two hours in the laboratory blunger until a slip of uniform consistency was obtained, and lawned through a 100 mesh lawn into a porcelain jar. The water contents of the three corner slips were obtained and from them the intermediate members were made by blending in such a way that the slips representing each body contained about 1.8 kilograms of dry weight.









The slips were next allowed to stiffen in plaster molds, and were thoroughly wedged by hand before any trial pieces were made.

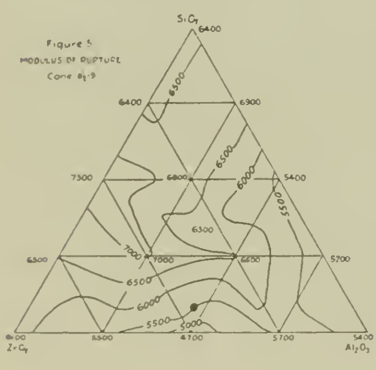
From each body the following test pieces were made:

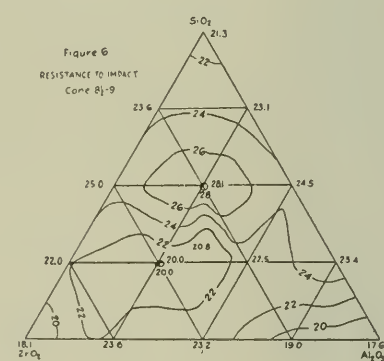
Trial Pieces

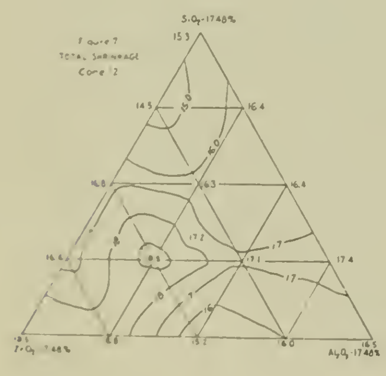
No. made	Test Pieces	Tests
9	Bars $4^1/_2'' \times {}^1/_2'' \times 1''$	Shrinkage
		Modulus of rupture
	(Broken bars)	Absorption
9	Discs $1^3/_4''$ dia. $^1/_2''$ thick	Resistance to temperature changes
9	Discs $1^3/_4''$ dia. $^1/_2''$ thick	Resistance to impact
	(Broken discs)	Dye penetration
2	Discs $1^3/_4''$ dia. $^1/_2''$ thick	Refired for absorption test.

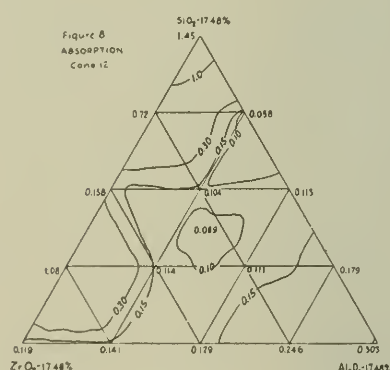
Drying and Firing

The test pieces dried thoroughly in air, so no attempt was made to dry them artificially. They were next placed in saggers with standard cones in each sagger, and fired in an up and down draft kiln. Half of the test pieces received a heat of cone $8^1/_2$–9, half received a heat of cone 12. Two discs from each body that had been fired at cone $8^1/_2$–9 were refired to cone $10^1/_2$ to give a better indication as to heat range.









Tests

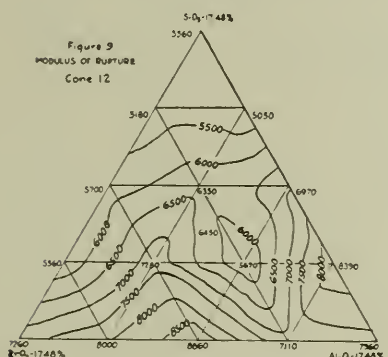
Shrinkage.—Linear drying and total shrinkages were measured on the rectangular bars which had shrinkage marks $2^1/_2''$ long on both sides. They were calculated in terms of wet length. The firing shrinkage was represented by the difference between the total and drying shrinkages.

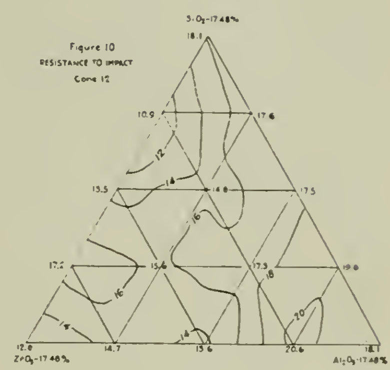
Transverse Strength.—The rectangular bars were broken in a Riehle transverse strength testing machine.

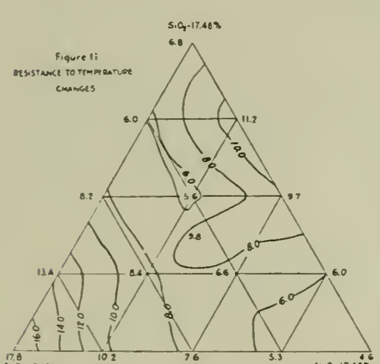
The following formula was used for calculations:

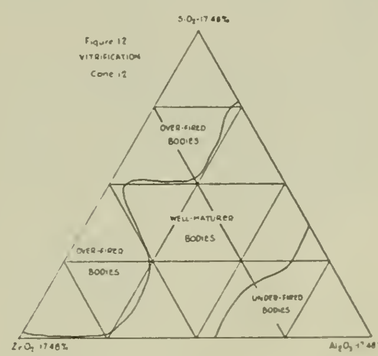
$$\text{Modulus of rupture} = 3/2\frac{PL}{bd^2}$$

P = breaking load in pounds.
L = span of the knife edges = $3^1/_2''$.
d = depth of the bar tested in inches.
b = breadth of the bar tested in inches.









Absorption.—Three broken bars of each body were selected for the absorption test. They were weighed dry, then immersed in water which was boiled during the 1st, 25th, 50th, 75th, and 100th hours of immersion. They were then weighed again wet.

$$\% \text{ absorption} = \frac{\text{Wet wt.} - \text{dry wt.} \times 100}{\text{Dry wt.}}$$

Heat Resistance Test.—(a) *On Test Pieces Fired to Cone 8$^1/_2$–9.* Four discs from each body were subjected to a test for resistance to sudden temperature changes. An oil-fired enameling furnace was used. The discs were subjected to a red heat (about 1600°F) for seven minutes; then immediately dropped into a tub of cold

water. The data given in the table represent the number of heats stood by the test pieces without breaking.

(b) *On Test Pieces Fired to Cone 12.*—Since the heat resistance test used on the discs fired to cone $8^1/_2$–9 proved to be too severe, a milder test was used on the discs fired to cone 12. The electric enameling furnace was used. Five discs of each body were placed in the preheating chamber at 450°F for 5 minutes and then transferred to the hot chamber at 1560°F for 7 minutes. While the discs were red hot they were dumped into cold water (60°F). When cooled they were immediately returned to the preheating chamber and the process repeated.

Impact Test.—The impact test consisted in dropping an 852 gram weight upon a disc. The weight was allowed to drop first from a height of $2^1/_2''$ above the top of the disc; then at increasing heights of $^1/_2''$ until the disc was broken. The top and bottom of the disc were covered with cardboard to prevent unequal pressure. The results were recorded in inches of drop required to break.

Dye Penetration Test.—The broken pieces from the impact test were subjected to a dye penetration test under a constant pressure of 250 lbs. per sq. in. for 16 hours. The varying degrees of porosity were designated as follows:

N. P. — Non-Porous — No penetration.
P — Porous — 1/16″ or less penetration.
V. P. — Very Porous — Over 1/16″ penetration.

SUMMARY OF DATA (CONE $8^1/_2$–9)

Body No	Shrinkage, % of Wet Length			Absorption, % of Dry Weight			Dye Test
	Drying	Burning	Total	Min.	Max.	Av.	
1	6.0	11.0	17.0	0.017	0.034	0.023	N.P.
2	6.0	.5	.5	.053	.155*	.054	N.P.
3	5.5	12.0	.5	.034	.063	.045	N.P.
4	.3	.2	.5	.049	.068	.055	N.P.
5	.3	11.6	16.9	.114	.118	.116	N.P.
6	4.9	10.9	15.8	.15	.196	.174	N.P.
7	5.5	11.6	17.1	.146	.212	.173	N.P.
8	.8	12.8	18.6	.078	.088	.083	N.P.
9	.2	11.7	16.9	.121	.127	.124	N.P.
10	6.0	.9	17.9	.042	.878	.358	P.

11	4.8	10.4	15.2	0.271	0.93	0.650	P.
12	5.5	12.2	17.7	.044	.087	.068	N.P.
13	.2	.1	.3	.13	.69	.328	N.P.
14	4.5	11.7	16.2	.792	1.26	.941	N.P.
15	5.1	10.8	15.9	3.37	3.90	3.56	V.P.
16	.3	10.0	.3	2.79	7.40	5.10	V.P.

	Modulus of Rupture. Lbs. per sq. in.			Resistance to Temperature Changes. Number of Heats Withstood			Impact Test. Inches of Drop		
Body No.	Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.
1	2780*	7700	6400	3	6	4.5	12.5*	22.0	21.3
2	4330	7560	6400	1	6	2.75	17.0	34.5	23.6
3	3790	9210	6900	4	6	5.0	15.0	37.0	.1
4	5200	8340	7300	1	6	2.25	17.5	28.5	25.0
5	5280	8150	6800	1	6	3.25	15.5*	30.0	28.1
6	4120	7650	5400	1	5	2.75	.0*	25.0	24.5
7	5130	7550	6300	1	3	.5	.5*	21.5	20.8
8	3270*	7950	6500	3	6	4.0	18.0	24.5	22.0
9	4470	8250	7000	1	5	2.75	17.0	22.0	20.0
10	5520	7760	6500	1	2	1.25	19.0	26.0	22.5
11	4610	7040	5200	2	3	2.50	21.5	29.5	25.4
12	4670	8400	6100	1	1	1.0	15.0	21.5	18.1
13	4750	6700	5550	1	3	.5	17.0	30.5	23.6
14	3770	5370	4700	1	6	3.25	20.0	27.0	.2
15	5030	6850	5700	1	3	1.5	15.0*	20.0	19.0
16	4050	7750	5400	1	7	3.5	13.0	24.0	17.6

* Extremely irregular figures discarded.

Comment on Results (Cone $8^1/_2$-9)

Total Shrinkage.—Figure 2 shows that the substitution of ZrO_2 for free SiO_2 slightly increases the shrinkage. The substitution of Al_2O_3 for the free SiO_2 decreases the shrinkage, due to the decreased vitrification. There are points of maximum shrinkage when 75% of the free SiO_2 is replaced by ZrO_2 or by 25% of ZrO_2 and 50% of Al_2O_3.

Absorption.—*Cone $8^1/_2$–9.* Figure 3 shows that the substitution of ZrO_2 for free SiO_2 gives a slight increase in absorption with a maximum absorption at 75%, ZrO_2 to 25% free SiO_2. An increase of Al_2O_3, at the expense of the free SiO_2 or ZrO_2 shows a great increase in absorption.

Modulus of Rupture.—Figure 5 shows a point of maximum strength at 50% of free SiO_2 replaced with ZrO_2. The substitu-

tion of Al_2O_3 for either free silica or ZrO_2 shows a decreased strength due to decreased vitrification.

Impact Strength.—Figure 6 shows the replacement of free SiO_2 by either ZrO_2 or Al_2O_3 up to approximately 50% gives bodies of increased resistance to impact. Maximum resistance to impact is reached with 50% of free SiO_2 replaced by 25% each of ZrO_2 and Al_2O_3.

Heat Resistance.—The heat resistance test was too severe and really shows little.

Summary of Data (Cone 12)

	Shrinkage, % of Wet Length			Absorption		
Body No.	Drying	Burning	Total	Min.	Max.	Av.
1	6.0	9.3	15.3	0.053	3.10	1.45
2	4.4	10.1	14.5	.224	1.67	0.72
3	5.5	.9	16.4	.094	0.063	.058
4	.2	11.6	.8	.147	.165	.158
5	5.0	.3	.3	.070	.125	.104
6	5.0	.4	.4	.082	.129	.113
7	.5	.7	17.2	.087	.093	.089
8	.2	.4	16.6	.222	2.12	1.08
9	6.2	13.3	19.5	.101	0.148	0.114
10	5.0	12.1	17.1	.094	.140	.111
11	5.0	12.4	.4	.158	.208	.179
12	.4	14.1	19.5	.112	.123	.119
13	5.0	13.8	18.8	.130	.163	.141
14	4.5	10.7	15.2	.126	.134	.129
15	.5	11.5	16.0	.234	.268	.246
16	5.0	.5	.5	.254	.370	.303

(Cone 12)

	Modulus of Rupture in Lbs. per square inch			Resistance to Temp. changes in No. of Heats Withstood.			Impact Test in Inches of Drops		
Body No.	Min.	Max.	Av	Min.	Max.	Av.	Min.	Max.	Av.
1	4150	6160	5560	5.0	10.0	6.8	15.0	18.0	16.1
2	3600	6250	5180	1.0	10.0	6.0	8.5	17.0	10.9
3	3190	6200	5050	5.0	23.0	11.2	.5	23.5	17.6
4	3740	8050	5700	4.0	14.0	8.2	11.0	16.0	13.5
5	5660	7030	6350	1.0	10.0	5.6	12.5	15.0	14.8
6	6230	8080	6970	6.0	17.0	9.7	16.0	19.0	17.5
7	5850	7500	6450	5.0	17.0	.8	14.0	22.0	18.2
8	4300	6900	5560	8.0	25.0	13.4	13.5	20.5	17.2
9	5850	8700	7280	5.0	10.0	8.2	13.0	18.5	15.6
10	3420	8110	5620	5.0	9.0	6.6	.5	22.5	17.3

11	7410	9350	8390	5.0	8.0	6.0	15.5	21.5	19.6
12	6720	7550	7260	7.0	25.0	17.8	7.1	17.0	12.0
13	7150	8950	8000	6.0	21.0	10.2	14.5	18.5	14.7
14	7870	9290	8860	5.0	10.0	7.6	10.0	16.5	13.6
15	6510	8000	7110	4.0	8.0	5.3	18.5	22.5	20.6
16	5200	9860	7360	3.0	8.0	4.6	15.0	22.0	18.1

Comment on Data

Total Shrinkage.—On the whole the total shrinkage increases with the increase of ZrO_2 at the expense of the flint. The same is true when Al_2O_3 replaces the flint. Bodies 9 and 12 have maximum shrinkage.

Absorption, Cone 12.—Minimum absorption is found in the bodies located in the middle of the triaxial diagram between the high and the low alumina. The 0.15% absorption contour lines form the boundry of the field of well matured bodies. Thus in general it may be said that 4 to 9% additions of Al_2O_3 as a refractory oxide in a porcelain body are desirable for the production of bodies with a long heat range.

Resistance to Temperature Changes.—ZrO_2 stands out as an ingredient which produces bodies capable of resisting temperature changes. The more ZrO_2 used in place of the flint, the greater is the resistance to temperature changes. Al_2O_3 seems to produce the opposite effect although the replacement of 25% of the flint with Al_2O_3 produces a good body with reference to its ability to stand temperature shocks.

Modulus of Rupture.—Bodies 1, 2, 4, and 8, are much lower in transverse strength at cone 12 than at cone $8^1/_2$ due to overburning. The bodies relatively high in Al_2O_3 show a much increased strength at cone 12 because of their increased vitrification. Bodies 11, 13, and 14 have the highest strength at this temperature. The results obtained are difficult to interpret. The increased transverse strength of these bodies at the higher temperature may be due to the formation of sillimanite.

Resistance to Impact.—On the whole the high alumina bodies are most resistant to impact. The bodies with high flint and high ZrO_2 show low impact values due to overburning.

COMPARISON OF DATA OBTAINED

Body No.	Absorption. % of Dry Wt. Cone 8½-9	10½	12	Modulus of Rupture. Lbs. per sq. in. Cone 8½-9	12	Resistance to Temp. Changes. No. of Heats. Cone 8½-9 *	12 *	Resistance to Impact. No. of Inches. Cone 8½-9	12
1	0.023	0.072	0.161	6400	5560	4.5	6.8	21.3	16.1
2	.054	.106	.142	6460	5180	2.7	6.0	23.6	10.9
3	.045	.106	.058	6900	5050	5.0	11.2	.1	17.6
4	.055	.117	.151	7300	5700	2.3	8.2	25.0	13.5
5	.116	.121	.104	6800	6350	3.3	5.6	28.1	14.8
6	.174	.119	.113	5400	6970	2.8	9.7	24.5	17.5
7	.173	.074	.089	6300	6450	.5	.8	20.8	18.2
8	.083	.061	1.08	6500	5560	4.0	13.4	22.0	17.2
9	.124	.093	.114	7000	7280	2.8	8.2	20.0	15.6
10	.358	.136	.111	6500	5620	1.3	6.6	22.5	17.3
11	.659	.169	.179	5200	8390	2.5	6.0	25.4	19.6
12	.068	.110	.119	6100	7260	1.0	17.8	18.1	12.0
13	.328	.134	.141	5550	8000	.5	10.2	23.6	14.7
14	.941	.163	.129	4700	8860	3.3	7.6	.2	13.6
15	3.56	.151	.246	5700	7110	1.5	5.3	14.0	20.6
16	5.10	.189	.303	5400	7360	4.5	4.6	17.6	18.1

* Comparison should not be made between these columns as different methods of testing were employed.

High alumina bodies Nos. 10, 11, 13, 14, 15 and 16 require a temperature higher than cone 9. Bodies 1, 2, 4, 8, and 12 become overfired at cone 12. Eliminating these, there remain bodies Nos. 3, 5, 6, 7, and 9, which have an unusually long vitrification range. Among these bodies No. 9 is considered to be the best. No. 3 is valuable for its long vitrification range and high resistance to heat shocks. Body No. 12 is valuable for its resistance to heat shocks. It should not be burned above cone 11.

Dielectric Test.—Since body No. 9 was considered the best one of the series, new batches of it were prepared and of body No. 1 in order to compare their dielectric strengths. The two bodies were blunged, lawned through a 60 mesh lawn and filter-pressed. Tubes of $^3/_4''$ outside diameter and $^7/_{16}''$ inside diameter were made by pressing each body through a die. These were cut into 8″ lengths. The high potential test was made at 60 cycles, using a 100,000 volt transformer. The current was applied near the center of the specimen through a band of tin foil $^1/_2''$ wide. The

interior electrode consisted of a column of mercury. During the test the specimen was immersed in oil. An initial voltage of 10,000 volts was applied and this was increased every ten seconds by increments of 5,000 volts until 25,000 volts was reached. Jumps of 2,500 were then used until 30,000 volts was reached. From 30,000 volts upwards the voltage was increased 1,000 volts every ten seconds until breakdown occurred. The results were consistent.

The averages of ten trials were as follows:

Body No. 1—150 volts per mil.
Body No. 9—145 volts per mil.

Conclusions

The Effects of the Use of Zirconia to Replace Flint.—(a) Overburning of the porcelain occurs at a lower temperature. (b) The ability to withstand sudden temperature changes is greatly increased. (c) The firing shrinkage is increased. (d) The transverse strength is highest with equal parts of zirconia and flint. (e) The color is poorer.

The Effects of the Use of Calcined Alumnia to Replace Flint. (a) The maturing temperature of the porcelain is greatly raised. A small amount of calcined alumina greatly decreases the danger of overburning. (b) The ability to withstand sudden temperature changes is greatly decreased. (c) The firing shrinkage is decreased. (d) When a body containing calcined alumina approaches vitrification, it has high transverse strength.

Dielectric Strength. The result of the dielectric test is disappointing since it is the reverse of what was expected. Under the conditions of the test the presence of free silica has a desirable effect on the dielectric strength.

Heat Resistance. The results indicate that zirconia is of great value in bodies which must stand sudden temperature changes. Of the three materials tested, flint is next in value to zirconia in this respect while calcined alumina is very poor.

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TESTS OF FIRE-BRICK MADE FROM GANISTER, FLINT CLAY, AND PLASTIC CLAY MIXTURES, WITH SPECIAL REFERENCE TO SPALLING[1]

By Raymond M. Howe[2] and Mark Sheppard[2]

ABSTRACT

Influence of the alumina-silica ratio on properties of fire-brick.—Five experimental batches of fire-brick were made by mixing various proportions of ganister, fiint clay and plastic clay in such a way as to vary the silica content from 53 to 77 per cent and the alumina content from 43 to 20 per cent. (1) **The fusion points** were found only slightly lower than those of corresponding pure silica-alumina mixtures. (2) **Load tests at high temperature** showed that the behavior under compression does not depend on chemical composition so much as on other factors such as the temperature of burning. (3) **The resistance to spalling,** as tested by alternate heating and dipping in cold water, was found to decrease as the temperature of burning was increased from 1300° to 1400°C. The higher silica bricks were relatively more resistant at the lower temperature but not so at 1400°C. Therefore the substitution of ganister for flint clay increases the resistance to spalling at moderate operating temperatures but is of no advantage at 1400° or above.

The influence of the alumina-silica ratio of fire-brick has been the subject of considerable discussion and has often led to a conflict of opinions. For example, bricks high in alumina often give unusually good service because of their high fusion points. Under other conditions these same brick give less satisfactory service than those which are high in silica. Therefore, five experimental batches of fire-brick were made under plant conditions from the raw materials described in table I in order to study the effect of varying the silica content. This variation was secured by replacing flint clay with ganister.

[1] Received January 31, 1920.

[2] Fellows, Refractories Manufacturers Association, Mellon Institute of Industrial Research, Pittsburgh, Pa.

TABLE I.—COMPOSITION OF MATERIALS USED.

	Flint clay	Plastic clay	Ganister
Silica	50.53	63.55	98.24
Alumina	46.35	29.19	0.98
Ferric oxide	2.30	2.39	.24
Lime	trace	0.52	trace
Magnesia	trace	1.36	0.12
Soda	0.81	1.00	.20
Potash	.51	.78	.18
TOTAL	100.32	99.79	100.20
Fusion point	Cone 34–35	Cone 26	Cone 33

The bricks were "hand-made" from the mixtures given below and had the indicated chemical composition and fusion point.

TABLE II.—COMPOSITION OF FIRE-BRICKS USED IN INVESTIGATION

Number	1	2	3	4	5
Parts ganister	0	10	30	40	50
Parts flint clay	80	70	50	40	30
Parts plastic clay	20	20	20	20	20
Fusion point	Cone 33	Cone 32–33	Cone 30–31	Cone 29–30	Cone 27
Silica per cent	52.95	57.87	67.26	72.14	77.04
Alumina per cent	42.95	38.34	29.35	24.81	20.28
Ferric oxide per cent	2.32	2.10	1.70	1.50	1.29
Lime per cent	0.10	0.10	0.10	0.10	0.10
Magnesia per cent	.31	.31	.31	.32	.33
Soda per cent	.67	.67	.67	.60	.54
Potash per cent	.67	.66	.66	.63	.60
TOTAL PER CENT	100.20	100.05	100.05	100.10	100.14

Specimens of each mixture were also subjected to the load, reheating and spalling tests. In some cases the tests were applied on the bricks as received; in other cases the reheating and load tests were used in conjunction and in several instances the spalling tests were preceded by reheating tests.

The load tests involved the standard temperature of 1350°C and a pressure of 25 pounds per square inch; the reheating tests were conducted over a period of 5 hours at the indicated temperatures. The spalling tests consisted of heating the specimens in the door of a furnace (operating at 1350°C) for one hour, partially immersing in a trough of running cold water, air-drying, and repeating the operation. The results of the various tests, with the necessary explanations, are given in table III.

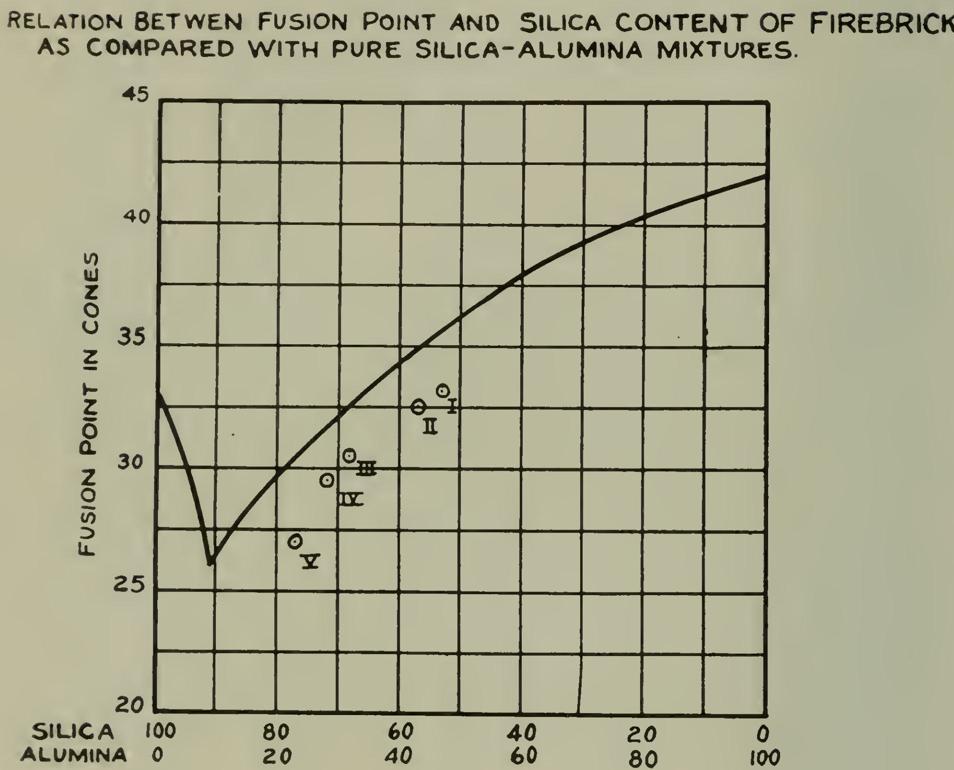

FIG. 1.

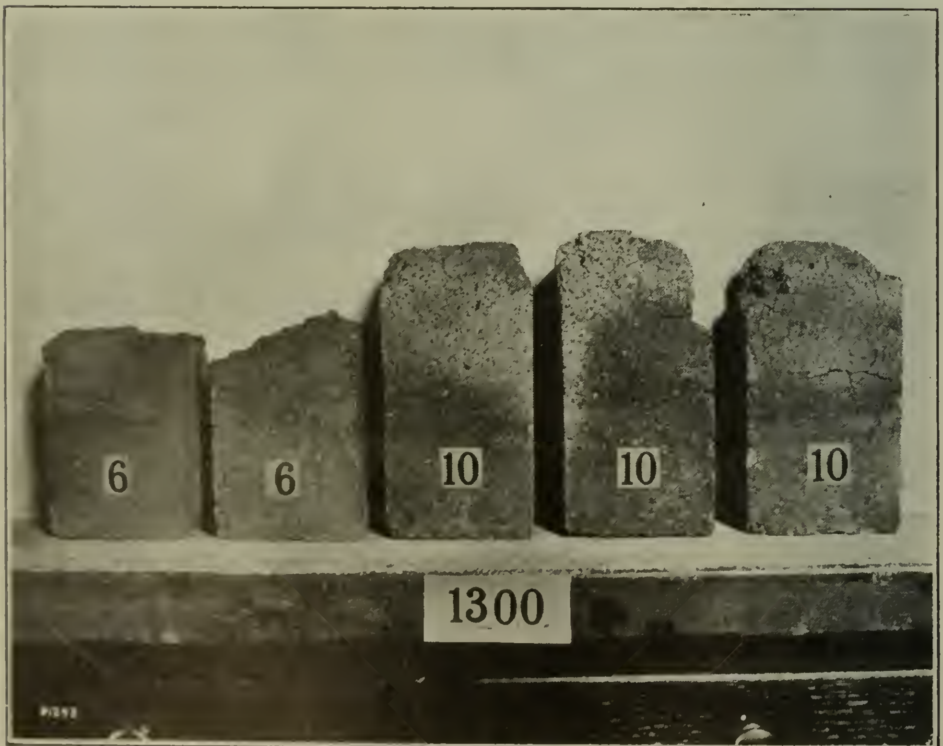

FIG. 2.—Condition of specimens 1 to 5 (left to right) after reburning at 1300°C and indicated number of dips.

Number of brick	1	2	3	4	5
Silica content of brick	52.95	57.87	67.26	72.14	77.04
Fusion point of brick	Cone 33	Cone $32^1/_2$	Cone $30-^1/_2$	Cone $29^1/_2$	Cone 27
Permanent linear change after heating five hrs. at 1300°C	0.00	0.16% contraction	0.22% contraction	0.16% contraction	0.16% contraction
Permanent linear change after heating five hrs. at 1400°C	.61% expansion	0.24% contraction	0.22% contraction	0.63% contraction	0.60% contraction
Per cent compression in 1350°C load test. Bricks tested as received	5.2	4.3	11.3	7.9	8.5
Per cent compression in 1350°C load test. Bricks first reburned 5 hrs. at 1300°C	4.2	5.4	8.3	10.8	10.0
Per cent compression in 1350°C load test. Bricks first reburned 5 hrs. at 1400°C	1.6	2.2	6.2	7.5	7.6
Per cent lost after 26 dips in spalling test. Bricks tested as received	1.0	2.0	3.0	4.0	4.0
Per cent lost after 6 dips in spalling test. Bricks heated 5 hrs. at 1300°C before testing for spalling	30.7	33.3	0.0	0.0	0.0
Per cent lost by same bricks after 10 dips	stopped at 6	stopped at 6	4.9	8.5	15.3
Per cent lost after 5 dips in spalling test. Bricks heated 5 hrs. at 1350°C before testing for spalling	50.0	50.0	0.0	0.0	0.0
Per cent lost by same bricks after 8 dips	stopped	stopped	20.0	8.0	15.0
Per cent lost after 4 dips in spalling test. Bricks heated 5 hrs. at 1400°C before testing for spalling	0.0	50.0	0.0	0.0	0.0
Per cent lost by same bricks after 5 dips	44.5	stopped at 4	0.0	36.3	39.8

DISCUSSION OF RESULTS

1. Fusion Points

The fusion points of the bricks decreased gradually as the silica content increased, and were usually about two cones lower than the fusion points of the corresponding alumina-silica mixtures. (See Fig. 1.) The tests were made both upon ground and chipped cones. The results are in accordance with the opinion that fusion points of fire-brick are controlled to a large

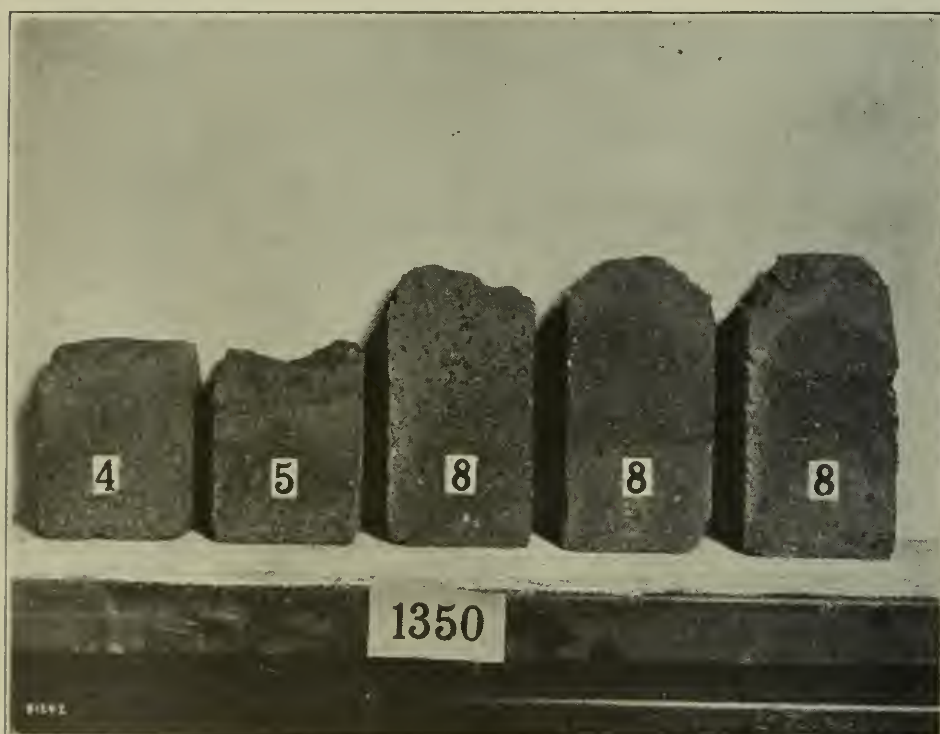

Fig. 3.—Condition of specimens 1 to 5 (left to right) after reburning at 1350°C and dipping the number of times indicated.

extent by their alumina and silica contents as well as by their impurities. A high alumina content is therefore desirable when the bricks are subjected to extremely high temperatures. This condition is found in electric, malleable iron, and grey-iron furnaces.

2. Behavior Under Load

When the chemical analyses of the five bricks are examined, it is evident that numbers 4 and 5 have the same compositions

as those brick which undergo little or no compression in the load test. Numbers 4 and 5, however, showed higher compressions than numbers 1 and 2, which are lower in silica. Consequently it was demonstrated that behavior under load at high temperatures is not a function of chemical composition, but of other factors.

One of these factors is the "burn" of the fire-brick, for the compression was decreased considerably by reburning at a higher

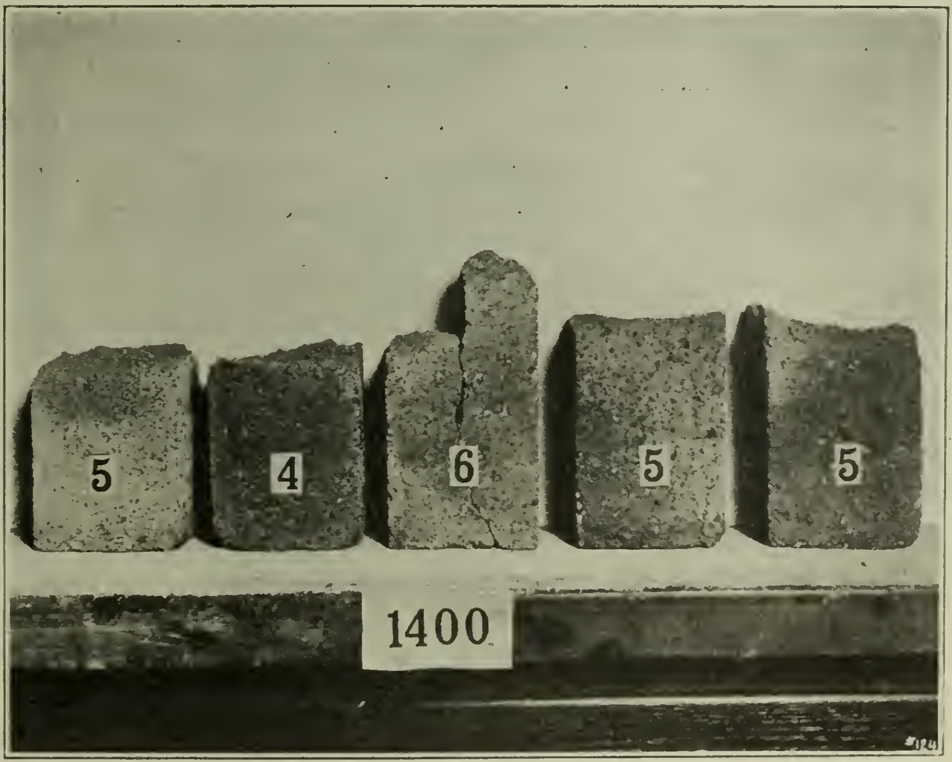

FIG. 4.—Condition of specimens 1 to 5 (left to right) after reburning at 1400°C and dipping the indicated number of times.

temperature. Apparently the tendency to contract under atmospheric pressure is developed more completely under the higher pressure of the load test.

3. Spalling

There was little to be learned from the spalling tests made upon the bricks which were tested as received. The fact that they were well bonded and free from lamination was demonstrated, but no other conclusions could be drawn.

When specimens were heated for five hours at 1300°C, prior to testing for spalling, more satisfactory results were obtained. Bricks numbers 1 and 2 became partially vitrified during reburning and failed after 6 dips in the spalling test. Numbers 3, 4, and 5 did not become partially vitrified in reburning and lost very little after 10 dips. (See Fig. 2.)

There was also a distinction between the bricks which were reburned for five hours at 1350°C, although the difference was less pronounced. When the bricks were first heated to 1400°C for five hours and then tested for spalling, numbers 1, 2, 3, 4, and 5 showed similar behaviors. (See Figs. 2 and 3.)

These tests, therefore, developed two facts: (1) The resistance to spalling of each brick decreased as it was subjected to higher temperatures. (2) The bricks containing ganister were most resistant to spalling at the lower temperatures, but this advantage was lost at 1400°C.[1] At still higher temperatures the more aluminous bricks would undoubtedly excel because of their higher fusion points.

Consequently the use of ganister should be highly desirable to prevent spalling in beehive coke oven shapes, but would not be justified in the manufacture of "bung" brick.

Conclusions

The opinion that the fusion point of a fire-brick is a function of chemical composition was verified, for the fusion points of the five bricks showed a close relationship to those of pure silica-alumina mixtures. This is not true for the behavior of a fire-brick under load at high temperatures, for those which should have shown the least compressions (judging by their chemical analysis) showed the most. The character of a fire-brick in this respect depends more upon the nature of the raw materials used and upon its physical characteristics. The substitution of ganister for flint clay increases the resistance of a fire-brick to spalling at moderate operating temperatures, but is of no advantage at the highest temperatures at which fire-brick are used.

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[1] In view of the load test results, conclusions drawn from brick of this type should not be applied to the silicious brick from New Jersey

SOME APPLICATIONS OF THE DRUM AND CABLE IN A BRICK PLANT

By Robert Twells, Jr.

ABSTRACT

Application of the drum and cable in a brick plant, for plowing and scraping the shale, for transferring it to the driers and out again and for carrying the burned bricks to the freight cars are described. The devices are simple and cheap, but they have effected a great saving and have made it much easier to get the necessary labor.

Introduction

In his address as retiring president R. T. Stull has called attention to the relative importance of the brick industry and its great need for what he terms "mechanical assistance." It is the purpose of the following article to describe certain labor-saving devices, in use in a face and paving brick plant, of such unique character that the writer believes their description may serve as a contribution to the knowledge of proper mechanical construction and arrangement of brick plants. The drum and cable system, used in many brick plants to draw the cars from pit to clay bin, with modifications, is the basis of most of these devices.

Method of Winning the Shale

The shale bank had originally presented considerable difficulty. The plant itself is in a valley closely surrounded on three sides by high steep ridges. It is necessary to lower the shale to the plant, sometimes using two levels and dumping the shale from one car to the next. The shale is fairly soft. Its strata are almost vertical, with streaks of rock at varying intervals. A steam shovel was practically out of the question due to the nature of the ground, and to the difficulty of avoiding the rock. As a result, hand shoveling was used.

The problem was solved in this way: A small frame building was built and mounted on low wheels so that it could be moved on a standard gauge track, the frame work of the building being

made strong enough to stand severe shock. Three drums are mounted in this car and connected to a 25 H. P. motor. The cable from one of these drums is fastened to the front end of either a plow or a scraper, and is used to pull them forward. The cable from the second drum is fastened to the back of either the plow or the scraper and is used to pull them back from another trip. The cable from the third drum is used to lower the clay car to the factory to be emptied and to draw it up again to be loaded.

The method of gathering the shale is simple. A heavy narrow plow without handles is drawn back and forth tearing up the shale. When enough has been torn loose to provide several hours work the cables are taken from the plow and fastened to an ordinary large drag scraper. The shale is scooped up and carried to a trestle where it is automatically dumped into a clay car. This system is very flexible. The digging machine may be placed upon the top of a bluff or in a hollow. The plow and scraper can work up or down a steep slope. The usual method of working is to build the clay car track close to a steep bank; a trestle is built over the track and the shale is dropped down the hill and dumped through the trestle into the clay car. In time the hill is worked away, and replaced by a shallow pit, probably 100 feet in diameter. The pit is always worked in such a way as to insure natural drainage. By slightly altering the position of the digging machine or by moving the trestle another supply of shale may be opened up for use.

The advantages of this method over hand digging are: (*a*) it saves the labor of 4 or 5 men; (*b*) it makes the work easier for the men; (*c*) it insures dry shale even in winter; (*d*) the location seldom needs changing; it stays in one place from 3 to 6 months; (*e*) it has great capacity; it "puts down" shale for 50,000 brick in 4 to 5 hours; (*f*) practically no repairs have been needed in three years; (*g*) no powder or dynamite are required; (*h*) it avoids ledges of rock which the explosives used in connection with hand digging, would scatter into the shale.

Moving the Stored Shale to the Dry Pans

The shale for use in bad weather is dumped from a trestle into a long shed adjoining the dry pans. A long conveyor belt was

tried, but it gave so much trouble that it was finally torn out and the shale was wheeled to the dry pans in barrows. This was not only expensive but labor for such work was almost unobtainable. The scraper system had been so satisfactory on the shale bank that a motor and two drums were installed in the storage shed. The shale is now being moved from anywhere in the shed to the dry pans. The same gang which ordinarily works the regular digger on the shale bank merely changes over to the other machine in bad weather instead of laying off to avoid wheeling shale.

The remainder of the labor-saving devices center about the hot end of the drier. The motor that turns the drier fan is also made to turn four drums which serve various purposes, as explained below.

Pulling the Cars from the Drier

Before the installation of this method it had been customary to stop the brick machine gang twice during the morning and afternoon to let down the cars in the drier. Half the men went to the cool end of the drier to push the cars; the other half went to the hot end to hold them from running too fast. A half hour of time was lost at each stop, and much confusion and many wrecked cars resulted.

This was remedied by placing a drum in the fan house and running the cable out to the front of the drier. By changing its direction with sheave wheels the cable could be made to pull in line with any tunnel. It was not considered practical to couple the cars together so the following method was used. A separate cable is placed in each tunnel. When the operator wishes to pull a string of cars, he enters the cool end of the drier and fastens the last car to the cable. To do this he uses a short piece of chain with a hook on one end and a clamp on the other. The clamp is similar to that used on a wire stretcher. It can be clamped to the cable at any place in the drier since the length of the string of cars is variable. After fastening the last car to the cable the operator returns to the hot end of the drier, fastens the pulling cable to the short length of cable in the tunnel, places his back against the first car to keep them from moving faster than the cable, applies the power, and walks out ahead of the cars. He applies the power by pulling on a rope which in

turn moves the belt on a tight-and-loose pulley on the drum. By this method one man can easily pull 100 cars from the drier in six hours. He draws them as they are needed, so there are always cool cars for the setters. There is practically no wreckage of the cars.

Power Transfer Car

The transfer car at the hot end of the drier gave some trouble. It became difficult to get men to pull it as the job was looked upon as a "man-killer." The setters on the more distant kilns lost time since they had to wait for the man to get back with a new car. An electrically driven car would have been satisfactory, but its cost and upkeep would have been high. It was therefore decided to use the drum and cable system. A stout frame was built near the transfer track and a driving shaft run to the frame from the dryer-fan motor. Two drums were mounted on the frame and geared to run in opposite directions. They were controlled by friction clutches. The cables from these drums were fastened one on each end of the transfer car. The operator merely stands at the frame and works his levers. He can "spot" the car quite accurately. The use of power for the transfer car did not save the labor of a man, but it made his work so much lighter, and so speeded up a lagging end of the plant that the change has been well worth while.

The drier car had to be pushed up an incline in order to give the necessary slant to enable it to run back to the machine room. This had always been a hard job for one man. It was therefore also eliminated by means of a small drum and clutch placed on the shaft between the fan house and the drums.

A Coal Handling Device

The coal for the kilns is dumped from the coal cars onto a trestle about a hundred feet from the fan house, at the hot end of the drier. A horse and cart is used to deliver coal to the kilns. The cart had first to be backed down under the trestle and filled by shovel. A track was therefore laid from the trestle to a platform high enough to enable a car of coal to be dumped directly into the cart. A cable from the fan house drum pulls the car up this incline. The power is applied in this case by pulling on a

rope which moves the belt to the drum of a tight-and-loose pulley. The car is very low and is easily filled. It holds just enough to fill the cart. Now one man loads the car while the other dumps the cart. The work is much easier on both, the kilns are soon coaled, and the men may be used to cart away bats and ashes.

New Labor Saving Service Planned

The drum and scraper method of handling shale has proved to be so satisfactory that the company is planning to tear out its high elevators, lower the pug mill and screens, and put in a scraper to draw the ground shale from the foot of the dry pans to the screens. They believe that by eliminating their elevators they can cut out at least half of their losses due to breakdown and repairs.

The plant has at present under construction a rather novel method of trying to solve the brick wheeling problem. This is more difficult on account of the flexibility which such a system must have. A temporary track built in easily movable sections is to be used. This will be laid between the kiln and the freight car or stock pile. Three temporary tracks will be laid into the kiln. The workman will place brick on low trucks, which will hold only 100 bricks so that they may be easily handled. There is a slight drop between the kiln and the freight cars which makes a gravity system possible. A drum will be placed at the kiln door; a cable, fastened to the loaded truck, will pass around the drum and will be fastened to an empty truck. In this way the full truck will pull the empty truck back to the kiln. The advantages of this plan are: (1) skilled men are no longer required; (2) it enables the men to work during bad weather since both ends are under cover; and (3) it speeds up production by emptying the kiln more quickly. This method has been tried out and found to be very successful.

The different devices described are essentially simple and their cost has been negligible, since, in most cases, they were built in the spare time of the regular blacksmith and carpenter, using, to a large extent, waste material. They have, however, effected a great saving and have enabled the company to compete success-

fully for labor against the lighter factory work. They are not new in principle nor could they be successfully applied to all plants but their description serves to show the possibilities of the drum and cable as a labor-saving device.

A SIMPLE EXPANSIBILITY TEST FOR DETERMINING THE WELDING PROPERTIES OF GLASSES[1]

By Donald E. Sharp

ABSTRACT

Simple method of determining the relative expansibilities of two glasses.—Place two rods of glass side by side with the ends flush, heat these ends, weld together by pinching with forceps and then pull out a thread or thin strip with the two glasses forming opposite sides. When cool the thread will bend toward the glass having the higher total expansion up to the softening point of the softer glass. This test may be used for quantitative **determination of coefficients of expansion** if a series of glasses of known expansibilities are available for comparison. The method is of particular value for investigating the **welding properties of glasses,** for whether or not two glasses can safely be welded together may be determined directly from the amount of curvature of the thread.

In the factory manipulation of colored and clear glasses, it is frequently found necessary to weld together two glasses, or to coat a thin layer of colored glass with a thicker layer of clear glass. The former is usually called welding or casing, and is employed in the manufacture of ornamental and fancy wares. The latter is called flashing, and applies particularly to the manufacture of colors such as copper ruby where the depth of color is so great that the glass must be blown very thin in order to transmit an appreciable amount of light. It is consequently necessary in the latter case to coat the thin layer of colored glass with a much heavier layer of clear glass to give the ware the requisite mechanical strength and "body" to bear working in the blowing room and in its later use. The manufacturer of glass laboratory apparatus also, must often join tubing from two different sources, or seal some tubing to a piece of apparatus from another maker. It, therefore, becomes a matter of importance to learn whether or not the two glasses will seal without subsequent fracture.

It has been found that some glasses of widely different com-

[1] Received, July 17, 1920.

position and physical properties can be welded together under certain circumstances and in certain shapes. The compound glass which has found some use for boiler gauge tubes is an excellent example of this kind of welding. These tubes are made by covering a layer of glass of one expansibility with a layer of glass of smaller expansibility. It is the difference in the expansion coefficients which in this case makes the compound gauge tube so tough.

In general, however, two glasses can not be welded or sealed together unless their coefficients of expansion are very nearly identical. In the compound tubes mentioned above it is possible to effect a seal, only because the strain is symmetrical and of such character that the forces brought into play in the weakest part of the tube are forces of compression rather than of tension.

Appert[1] suggests that the conditions necessary for successful welding are: (*a*) The glasses must have the same coefficients of thermal expansion over the range of temperature to which the finished articles are likely to be submitted; (*b*) the diathermancies, or power of transmitting heat, must be equal; (*c*) the glasses must be inert and sustain no change whatever during the heating necessary in welding. He states also that the first condition is the most important and applies to all cases while the other two are only of secondary importance. A method of determining the state of tension existing between two glasses, which is described in detail in his article, might, indeed, find good application in the blowing room of a glass factory.

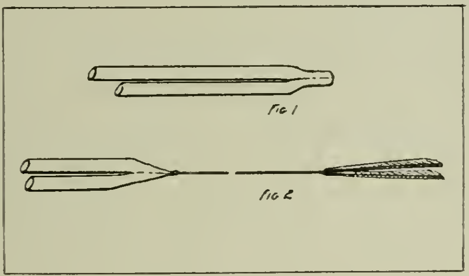
This method consists of blowing three bulbs from combinations of the two glasses under test. Calling the glasses A and B; one of the bulbs is blown of A glass alone and is reserved as the standard. The other two bulbs are made of both A and B glasses—number 1 of a layer of A coated with a layer of B, and number 2 of a layer of B coated with A. The determination of the welding properties of the two glasses is then made by finding the resistance of numbers 1 and 2 to shock, as compared with the standard bulb of A glass. If the glasses differ in expansibility one of the bulbs is likely to burst violently while the other will be very resistant to shock due to the similarity to toughened or oil-

[1] Appert, *Bull. Soc. d'encour. l'ind nat.*, Jan., Feb., 1919.

hardened glass. When the bulbs number 1 and 2 do not seem to differ from the standard in their susceptibility to breakage or to cutting with the diamond, the bulbs are perfectly sealed and no state of tension exists.

While this test is undoubtedly satisfactory for use in the blowing room of a glass factory where the glass may be had in quantity, and may be manipulated on the blowing iron, it is not suitable for laboratory use, nor is it convenient for the lampworker's use before the blast flame. A method that has been used by the author for several years, and found very satisfactory, permits a test in the laboratory by means of a blast lamp, and is both quick and reliable. It has also the advantage of requiring only very small pieces of the glass under test.

The two glasses, whose properties of sealing together are to be tested, are worked out before the blast lamp or over a Meker burner into small rods. The ends of these rods are then heated



to softness and the two rods held together, and along side of one another, so that the ends which were softened weld together and form a single rod (Fig. 1). The junction is now carefully heated to softness and shaped slightly with a pair of forceps, into a form which may easily be pulled out. The end of the junction is now seized with the forceps in order to support it, and the flame allowed to strike on the thinner area of the compound strip that has been formed, in such a manner as to heat both glasses equally. As soon as the junction is soft enough, the rods are removed from the flame, still being held with the forceps, and the junction pulled out quickly into a thin strip or thread about 10–15 inches long, the tension being maintained until the softened glass has cooled below its deformation temperature (Fig. 2). The heavy end formerly held in the forceps

is now broken off and the thread held in a vertical position for examination.

The thin thread formed by drawing out the junction of the two pieces of cane is in reality a strip similar to the familiar metal thermostat. If the glasses composing the strip have different coefficients of expansion, a greater contraction occurs on one side of the strip than on the other and the strip bends into a curve, the glass of higher coefficient of expansion being on the inside of the curve. Glasses differing greatly in expansibility will give strips that will actually wind up into spirals when the tension is released, while those differing but little will show only a very slight departure from straightness. No curvature at all would, of course, be an indication that the glasses had identical expansion coefficients.

In employing this test as a criterion for satisfactory welding, it has been found that a very slight curvature, that is, a small difference in expansibility, indicates that the glasses will weld together without subsequent fracture, if well annealed. If the strip is absolutely straight there is no doubt that the two glasses may be used for any type of cased ware or for blowing even the most delicate apparatus before the blast lamp. A curvature of any appreciable amount, however, means that a satisfactory product can not be made of the glass combination.

Although the most frequent use of a test of this sort would doubtless be to determine whether or not two glasses had the same expansibility without regard for the amount of this expansibility, still the method can be made a quantitative one in a very simple manner.

A number of glass rods of small diameter and known expansion coefficients are obtained, ranging in value from 0.0000030 to 0.000011 by steps of about five in the seventh decimal place. This requires about sixteen or more different glasses. A suitable rack or tray should be provided and properly labeled so that easy access may be had to each variety.

If it is desired to determine the expansion coefficient of a new glass, a sealing test such as has been described above is made on the sample, using as a standard the one of the glasses of known expansibility which the experimental glass is judged to be most

nearly like. From the result of this test the operator can easily tell in which direction the expansibility of the new glass lies, and a different standard is tested against it, until two known samples are found, one of higher and one of lower expansibility than the unknown. It now becomes easy to estimate within one or two units in the seventh decimal place, what is the coefficient of the unknown glass. By pulling the strip out rapidly into a fine thread the delicacy of the test is much increased and the method becomes very accurate.

The use of this method involves neither delicate apparatus nor a skilled operator, but may be used by a novice with almost no experience with a blast lamp. The standards must of course, be obtained by direct measurement or from a factory in which the expansion coefficients of the glasses have been accurately determined by careful laboratory methods.

In employing this test for factory control and laboratory experimentation in the several years it has been in use by the author, he has never been disappointed by obtaining misleading results. Several times actual measurements have been made to confirm the values arrived at by this method and in no case have the two methods failed to agree.

In conclusion, the author would like to express his thanks to Dr. J. T. Littleton of the Corning Glass Works, who very kindly permitted the publication of this article.

HAMBURG, N. Y.

THE DESIGN AND OPERATION OF GLASS HOUSE FURNACES*

By F. J. Denk

ABSTRACT

Design and operation of glass house producer-gas furnaces.—After discussing the proper design of checker chambers, two inefficient designs are criticised. The gases being cooled should move downward and the gases being heated should move upward, and the dimensions should be based on actual working data. The location of the ports is important and heat insulation should be carefully considered. The reversing valve should be efficient and operated regularly; and the performance of the furnace should be constantly watched with the help of instruments such as draft recorders and thermocouples, and the waste gases should be analyzed frequently. With care in design and operation it should be possible to approach the performance of a certain furnace which gave 3 lbs. of glass for each pound of coal burned.

Many of the present pot furnaces and tanks have been built with the intention of using mainly natural gas, but provision has been made for the application of producer gas, by including a set of gas regenerating chambers to take care of the new fuel. The arrangement is, in many cases, made in such a way, that the preheating chambers are used for the air as long as natural gas is applied, while the other set of chambers is closed up.

As the regenerating chambers form one of the most important parts of a furnace, something may be said about their design and layout.

The capacity of the regenerating chambers is too often inadequate for the conditions under which they are supposed to work. This may be due to the application of an old "rule of thumb" method in designing the chambers, a method which was all right, as long as only natural gas had to be dealt with, since this gas, being practically of uniform pressure, temperature, and composition, always required the same quantity of air. Conditions, however, are different with producer gas. When laying out a plant and designing a furnace for this fuel, careful attention should be paid

* Received February 7, 1921.

to the conditions, under which the gas enters the checker chambers. The temperature and composition of this gas are important factors in the design. Needless to say, the designer can not take care of irregular operating conditions due to carelessness or ignorance on the part of the operators; for instance, in the gas producer plant. On the other hand, he should not assume best possible working conditions, because they may happen only once in a long while. The designer must know, therefore, what can be expected from a certain class of laborers, from a certain type of gas producers, and from a certain grade of coal, and this knowledge will give him enough points for his calculations.

The design is correct, when the desired furnace temperature can be obtained and maintained. In order to have a uniform temperature all over the hearth, it is necessary to provide for a uniform progress of the combustion reactions. This condition can be obtained by giving those gases, which are not yet completely consumed, a chance to burn completely, by adapting the combustion space to the existing conditions, and by forcing the highly heated gases of combustion to heat the bath or the pots in the most efficient manner.

The arrangement of the checker chambers should be such that the currents of hot gas, which are supposed to heat the cooler bricks uniformly, must flow in a downward direction, whereas the currents of cold gas, which are supposed to cool the hotter bricks and attain a higher temperature themselves, must flow in an upward direction.

The reason for such an arrangement is evident. The hot gases entering at the top will give up their heat to the colder bricks, thus becoming cooler the farther down they travel. But the cooler the gases, the heavier they will become and the result is a natural descent of the waste gases in the direction of the outlet, *i. e.*, towards the stack connection. The opposite will take place after the valves have been reversed, that is, cold gases will enter the chambers on the bottom and, coming in contact with the hot bricks, they themselves become hotter, expand, become lighter, and rise.

In this connection a few remarks about the height of the furnace stack may be made, which have a bearing on the conditions ex-

plained in the preceding paragraph. It is sometimes stated, that on account of the hot gases being forced downward through the checker chambers, an additional height must be provided in the stack to overcome the natural tendency of the hot gases to move upward. This statement is, as explained above, not correct, because if the checkers are laid out in the manner indicated, the natural passage of the gases will be downward; the height of the stack should, therefore be figured from the point, where the gases leave the chambers, *i. e.*, from the bottom.

The chambers should be grouped as far as possible in one block, in order to reduce the radiation losses to a minimum. For the same reason the walls should not be less than 18″ thick, unless, of course, local conditions should interfere. The partition walls should be of the same thickness to prevent leakage through them, which would cause gas and air to mix and to burn in the chambers instead of in the furnace. Here, too, local conditions may forbid the erection of walls of such thickness, but in such cases they should be built with the utmost care, the bricks being laid in a good cement and coated with a gas tight surfacing material.

To prevent radiation losses as much as possible, the chambers and uptakes should be covered with a good insulating material, wherever the walls are exposed to the outside air. On the furnace proper, care must be taken not to go too far with the insulation. On a tank, for instance, the lower part should never be covered, because there would be danger of the molten glass eating up the side blocks, thus destroying the hearth. Of course, to leave the sides uncovered means a heat loss, but this loss can not be prevented except at the sacrifice of the whole tank.

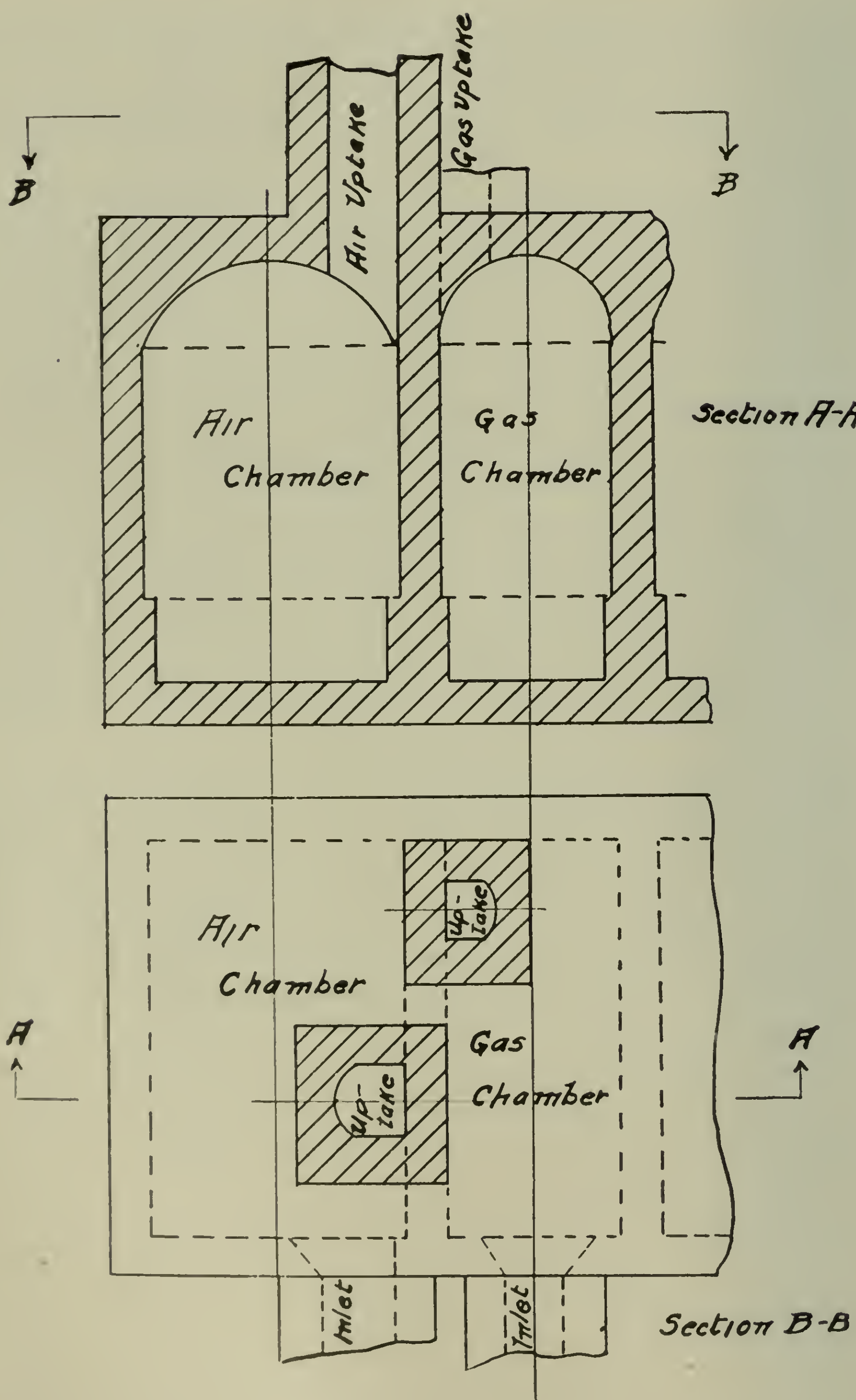
The best thermal efficiency will be obtained with chambers having the longer axis vertical. They should be arranged so that as much of the checker work can be utilized as possible and the formation of "dead pockets" is eliminated. It is hardly ever possible, on account of practical considerations, to give the chambers a theoretically perfect form. It should, however, be the aim of the designing engineer to try to follow those theoretical outlines as much as he can in order to prevent dead pockets and, therefore, unnecessary waste. The main disadvantage of hori-

zontal chambers lies in the resistance which they offer the unobstructed flow of the gases.

The accompanying sketches of checker chambers illustrate certain incorrect methods of design which are sometimes found in practice.

Figure 1 shows a rather common arrangement of the air and gas chambers for an end port tank. The general design of the chambers is nearly vertical, and should give a good utilization of the available heat, but this advantage is offset by the arrangement of the inlets and outlets for gas and air. The location of the gas inlet is nearly correct although it might, to advantage, have been flared out so as to cover the whole width of the chamber. The gas outlet, however, is in the wrong place, leaving the gas chambers along the partition wall instead of being flared out and reaching over the whole top. The result is a dead pocket opposite the outlet. Conditions are worse in the air chamber. Here the inlet is located in the elongation of the partition wall and the outlet is almost vertically above it, thus making a dead pocket out of about three quarters of the volume of the chamber. An arrangement of this kind, is, of course, entirely wrong.

But the location and arrangement of the uptakes as shown must be objected to for another reason also. The hot gases, coming with a high velocity from the furnace, impinge with full force against the bricks. They are then reflected and form eddy currents along the crown, thus making impossible a uniform working of the chamber. The latter can only be obtained when the velocity of the waste gas currents in the space between checker bricks and top of the chambers is reduced to zero or at least to nearly zero. A simple method of doing this is to increase gradually the sectional area of the downtakes, or, in other words, to flare them out from a certain distance above the chamber to the crown. This flaring out can be done on all four sides, thus giving the uptakes the form of the frustrum of a pyramid. The insertion of a slag pocket will answer the same purpose, but for lack of space such slag pockets are not very often found on tanks. On pot furnaces, slag pockets can easily be provided for on the bottom of the eyes, the gas and air connections to the chambers being taken off a little distance below the bench. In order to prevent


B
B
Air Uptake
Gas Uptake
Air
Chamber
Gas
Chamber
Section A-A
Air
Chamber
Up-
take
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take
Gas
Chamber
A
A
Inlet
Inlet
Section B-B

FIG. 1.

molten glass from a broken pot running down into the chambers through the ducts, provision is made on top of the openings to divert the flow of the molten glass and force it to drop or run down into the pocket, whence it can be removed without disturbing the working of the furnace. Such an arrangement is shown in figure 2, the arrows indicating the flow of the molten glass.

Figure 3 illustrates another arrangement of vertical chambers, which is inefficient, and wrongly designed. Here the gas currents are forced, by means of vertical partition walls, alternately

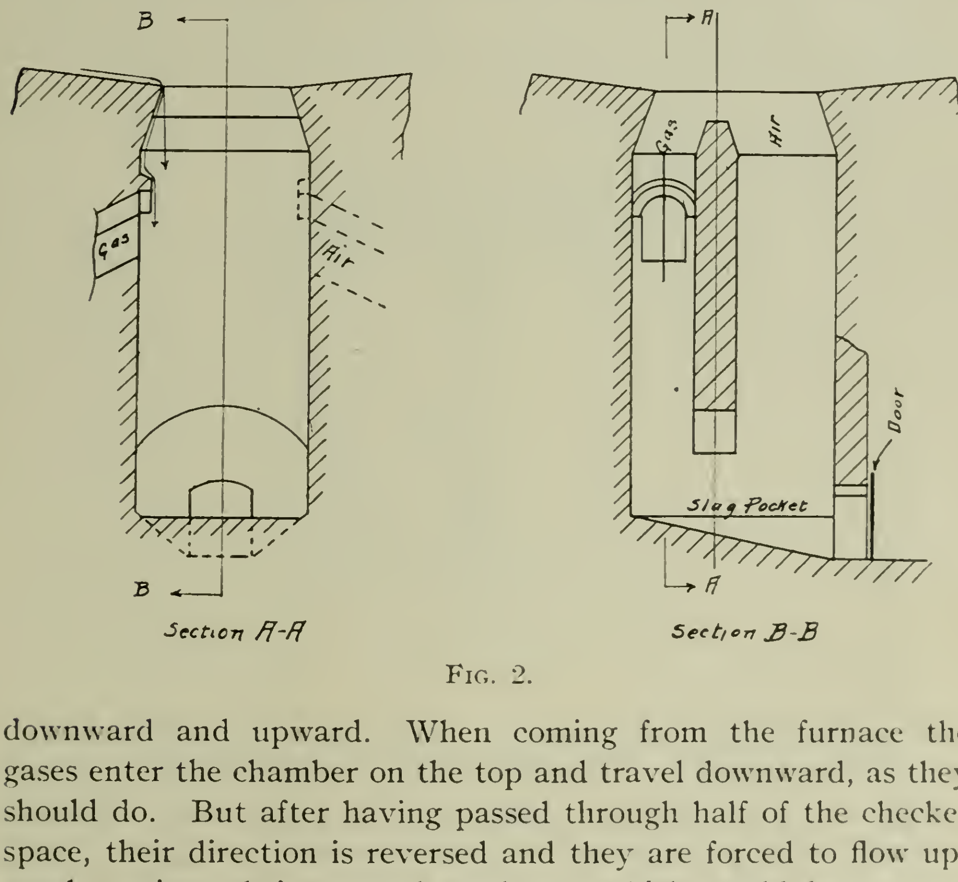

FIG. 2.

downward and upward. When coming from the furnace the gases enter the chamber on the top and travel downward, as they should do. But after having passed through half of the checker space, their direction is reversed and they are forced to flow upward, against their natural tendency, which would be to continue in a downward direction, since they are becoming denser and therefore heavier, the farther they travel. Thus a pocket filled with hot immovable gases, will be formed on the bottom below the bricks, which will prevent the regular working of the checker chamber.

Horizontal chambers, *i. e.*, chambers, having the longer axis

horizontal, are seldom found in glass plants. It is true, the chambers of side port tanks are horizontal in form, but they are actually vertical chambers, because the outlets are on the top and furthermore, the chambers are often subdivided into compartments having a common flue along the bottom. They work, therefore, entirely like vertical chambers and, when the uptakes are arranged along the division walls between the chambers as shown in figure 1, labor under the same disadvantages as the vertical ones.

It was stated above that as a rule the volume of the checker chambers is too small, due perhaps to the application of an old "rule

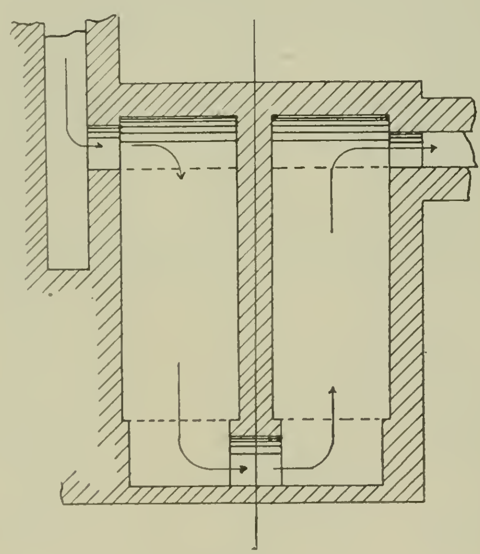

Fig. 3.

of thumb" method of designing. The same holds good for other parts of the furnace. The design of gas and air flues, uptakes, ports, etc., has mostly been guessed at, and no one has taken the trouble to check the actual conditions, chiefly in regard to actual velocities. Thus it happens, that widely varying data can be obtained from different furnaces or other appliances of the same size and type. Here lies one of the main uncertainties in the design of glass house furnaces. I have investigated this matter carefully and have collected a set of data in regard to temperature, pressure and velocity of gas and air in the different parts of a furnace, which I have applied with good success to new installa-

tion and which have shown me, that "guesswork" or "rule of thumb" methods can be and must be avoided, if we want our furnaces to work economically and satisfactorily. To show the fallacy of such methods in a somewhat exaggerated case, I may mention the following.

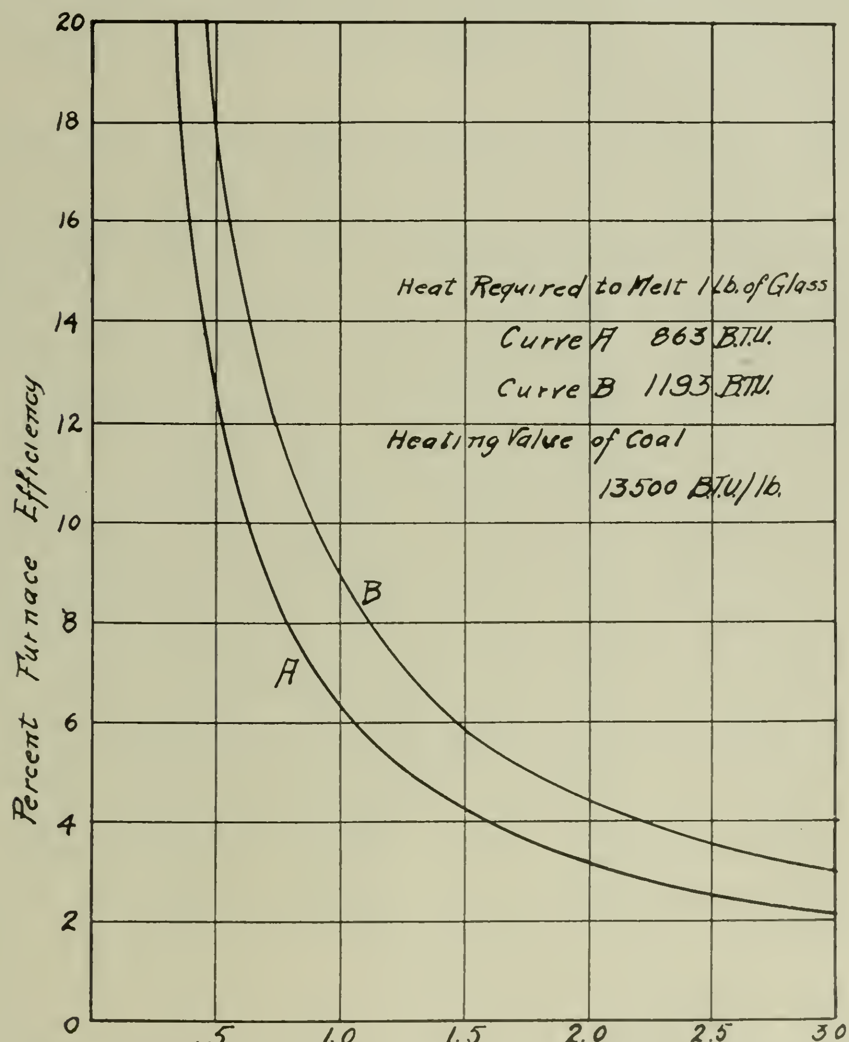

FIG. 4.—Lbs. of coal per lb. of glass. Ratio between furnace efficiency and quantity of fuel used.

There is a rule used by the designers, which makes the area of the ports equal to a certain percentage of the area of the hearth. Now supposing the hearth area of an endport tank is to be 400 square feet in the melting end, would it be good practice to make

the port areas the same irrespective of whether the hearth were square or rectangular? Certainly not, because if the area were correct for the square hearth, it would be too large for the rectangular hearth, for the reason that the gases emanating from it would not have force enough behind them to travel around. This shows how cautiously these rules should be handled. It is best to disregard them altogether and to base the calculations on good working practice.

Similar conditions can be found in the hearth. The distance between the top of the metal and the crown should be such that for a given width and a certain velocity of the gases the sojourn of the hot gases is timed to give the best possible utilization of the heat. We must keep in mind that heat is not transmitted to our furnaces by radiation, notwithstanding a widely spread belief to the contrary, but mostly by convection or contact between the hot gases and the bath and this heat transmission will be the better, the higher the temperature difference. For this reason, the gases must remain over the bath long enough to enable them to give up their heat to the molten glass. If the vertical area of the hearth is too small, the gases will carry part of their useful heat into the stack, and if the vertical section of the hearth is too large, the velocity of the hot gases will be reduced considerably—in extreme cases even to zero—and they will follow their natural tendency to rise, thus heating the crown instead of the bath.

We must keep in mind also that our furnaces are working with a low efficiency for this reason. Everything possible should be tried to improve operation and reduce the preventable fuel losses to a minimum. Figure 4 shows two curves, illustrating the relation between furnace efficiency and quantity of fuel consumed. Curve A represents a glass requiring 863 B. t. u. per pound, and curve B a glass requiring 1193 B.t.u. per pound. These two figures represent approximately the limits of average practice, with the exception of certain special melts. The worst condition that has come under my observation, is an oil fired furnace, requiring an equivalent of 2.6 pounds of coal per pound of glass. This corresponds to about $2^1/_4$ per cent efficiency for curve A, and to about $2^3/_4$ per cent efficiency for curve B. The best performance encountered was equivalent of $^1/_3$ pound of coal per pound of

glass. It was found in the case of a producer-gas fired side port tank, giving an efficiency of over 20 per cent. It is hardly possible to excel this performance with our present type of furnaces, but there is no reason why it should not be approached more closely than is usually the case. A glance at the curves will show that from about 1.5 pounds of coal down, a slight reduction in

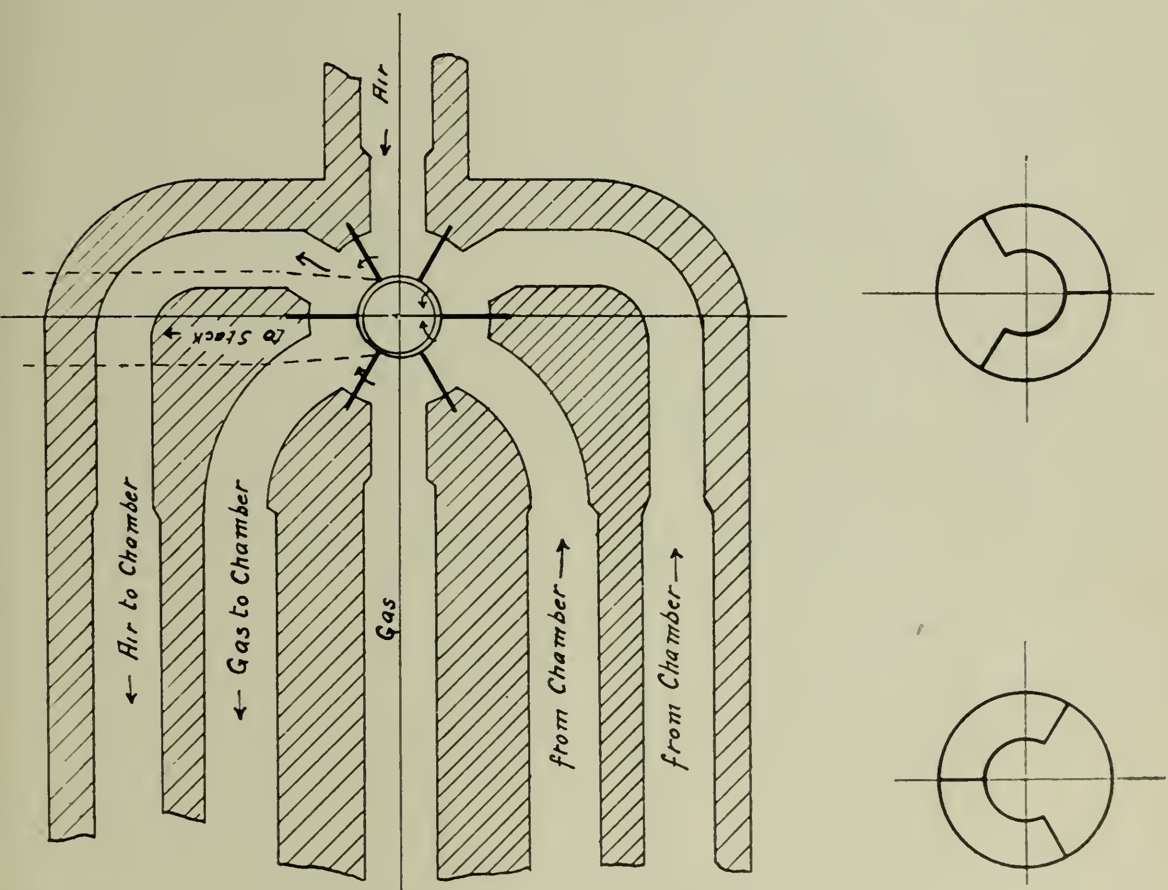

Fig. 5.—Combination gas and air-reversing valve.

fuel will increase considerably the efficiency of the furnace. Such a reduction can be obtained, (1) by a correct design of the chambers and the furnace as explained above, and (2) by careful selection and arrangement of the proper auxiliaries.

The gas flues between producer and furnace should be covered with a good insulating material, unless they are laid under ground. This is not very important for the working of the furnace, be-

cause the heat lost by radiation in uncovered mains will be regained in the checker chambers, but it makes a big difference whether the gas enters the chambers at say, 1300°F or at only 700°F. In the first instance, the gas chambers can be made much smaller than in the second, thus saving space and reducing

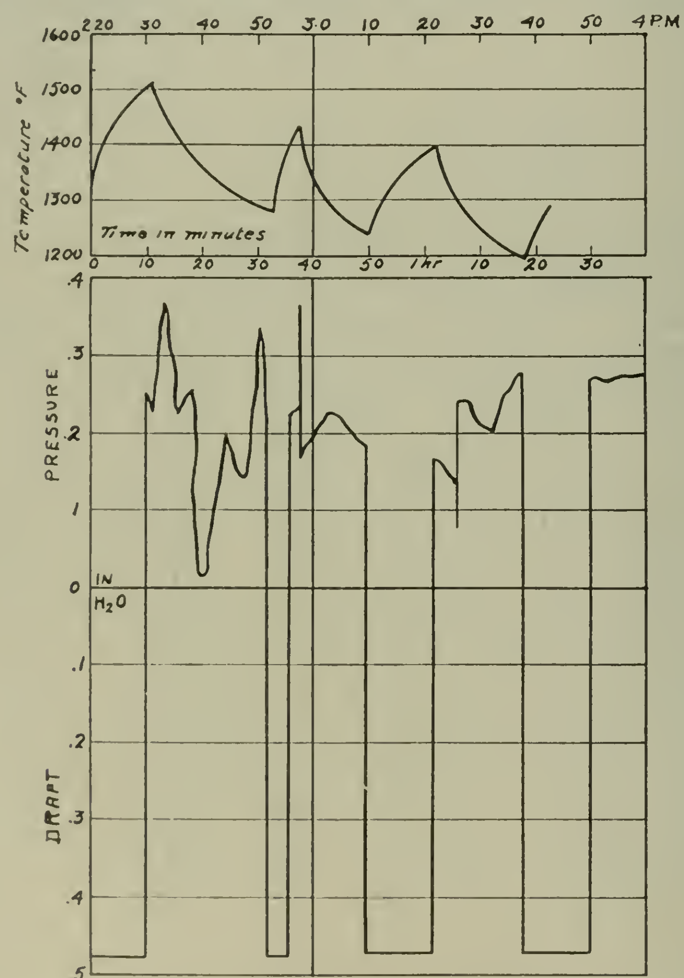

FIG. 6.—Chart showing influence of reversals on temperature of checkers.

the radiating surface. Furthermore the heat not used in the checker chamber can be utilized in waste heat boilers to generate the steam for the producers. Thus, although there is no direct influence on the working of the furnace by covering the lines, the indirect influence is of considerable importance and should not be neglected.

Another item to be watched carefully, is the selection of a good type of reversing valve. If this is not attended to, a loss of gas will occur which may amount to as much as 3 per cent or more. The best type, however, will work inefficiently, if reversing can not be done in the shortest possible time. A short lever arrangement is the best for this work. Hand wheels should never be applied as they result in a large loss of gas up the stack.

A very inefficient type of a reversing valve is shown in figure 5. It is a combined gas and air valve, designed to save space. It does save space but efficiency is sacrificed. The upper part shows a layout of the valve with the corresponding gas and air ducts and the stack connections, while below are shown two horizontal sections of the valve proper illustrating the two positions. Besides a large loss of gas during reversal, there is a possibility of frequent explosions which may damage the whole arrangement.

A few words may be said about the operation of the valves. Irregular reversal means irregular working of the furnace. Figure 6 illustrates the influence of irregular reversing on the temperature of the checker chambers. The lower part of the curves is obtained by means of a recording draft gauge, located between the chambers and the valve whereas the upper curve is plotted from observations made with a pyrometer in the checker chamber. It can easily be seen that the short periods during which the chambers are connected to the stack cause a decided drop in the temperature of the checkers, which, in turn, will have a decided influence on the working of the furnace. Regular reversals will prevent such occurrences.

To get the best possible operation of a given furnace, it should be under constant observation. This can be done only by means of suitable instruments, located at the right places.

In the first place, draft recorders should be employed, which enable the operator to control the working of the chamber. Clogging of the bricks can be detected in this way and unnecessary fuel losses followed by too high stack temperatures, can be prevented. The temperatures of the furnace chamber and stack should also be under constant observation, which may be done by a switchboard suitably arranged to show the temperatures at the different points. In the furnace and in the chambers a platinum-platinum-

rhodium couple must be employed, while in the stack a base metal couple can be used. Care must be taken to protect the platinum-platinum-rhodium couple from direct contact with hot gases, because they make the platinum brittle and thus ineffective. Finally, regular analyses of the waste gases should be made in order to ascertain whether combustion is complete or not. Such analyses are easily made and do not require a large and costly outfit.

If the rules laid down and explained above are followed, there is no reason why we should not be able to secure an efficient and satisfactory working of our furnaces.

PITTSBURGH, PA.

CERAMIC ABSTRACTS

Author Index[1] to Abstracts for March

[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. **Reorganization of instruction in ceramics.** REISENEGGER, Berlin-Dahlem. *Ber. d. Tech.-wiss. Abt. d. Ver. keram. Gewerke.*, **5**, Pt. 5, 4–7 (1919).—A plea is made for the establishment of ceramic instruction and research in the technical high schools to enable Germany to regain its world supremacy in the markets for ceramic products. E. N. BUNTING.

2. **The ceramic industries.** EDWARD W. WASHBURN. Univ. of Ill. *Tech. Eng. News*, **1**, No. 8, 1 (1920).—A brief discussion of the field covered by the ceramic industries, their importance in modern life, the need of research, and the opportunities which exist for the technically trained man in this industrial field. Ed.

3. **Transferring designs to ceramic ware.** WILHELM SCHERTEL, Selb. *Ber. d. Tech.-wiss. Abt. d. Ver. keram. Gewerke*, **5**, Pt. 5, 34–40 (1919).—Methods of transferring ornamental designs and pictures to ceramic ware are described. Usually the lithographic method is used, although relief printing is also practiced. Many problems in this field await solution E. N. B.

4. **The mechanical properties of ceramic bodies and methods of measuring them.** ERNST ROSENTHAL, Selb. *Ber. d. Tech.-Wiss. Abt. d. Ver. keram. Gewerke.*, **5**, Pt. 5, 23–33 (1919).—Methods, with photographs, of determining the resistance of bodies to pressure, torsion, bending, tension and sudden blows, are given. These mechanical properties depend greatly upon the structure of the material and the degree of vitrification. More attention should be given to the measurement of these mechanical properties and to their dependence on the composition, structure and heat treatment of the bodies. E. N. BUNTING.

5. **Instruction in ceramics in the technical high school at Charlottenburg.** ANON. *Ber. d. Deut. Keram. Gesell.*, **1**, Pt. 1, 38–40 (1920).—Instruction and research under Dr. R. Ricke is now being carried on and the establishment of a separate department of ceramics is contemplated. E. N. BUNTING.

PATENTS

6. **Drier for clay or ceramic products.** ITHAMAR M. JUSTICE. U. S. 1,360,645, Nov. 30, 1920.—The combination consists of drying tunnels having receiving and delivering ends, means for moving the product through the tunnels, fuel tunnels extending beneath the drying tunnels, a stack connected to the fuel tunnels, channels communicating with the stack and with the drying tunnels and air inlets for the receiving ends of the drying tunnels, whereby air introduced into the drying tunnels at the receiving ends thereof will be gradually increased in temperature as it passes through the drying tunnels.

7. **Pottery-ware.** ARTHUR PERCY MORRIS. Insein, Burma, India. 1,362,956, Dec. 21, 1920.—The process for figuring "Burmese black" pottery, consisting in removing the carbon blackening by oxidiaton thereof, over a predetermined area, to reveal the natural color of the clay. C. W. SAEGER, JR.

Apparatus and Instruments

8. Prize awards of the German Ceramic Society. M. HEINE. Bonn. *Ber. d. Deut. Keram. Gesell.*, **1**, Pt. 1, 7–23 (1920).—Due to shortage in cotton cloth during the war, prizes were offered in 1918 for new methods of preparing clay slips, using little or no filter cloth. Centrifuge methods were found, useless, as the constituents of a mixture separate and the resulting mass is not homogeneous. Suction filters also could not be used, as only a thin layer separates which becomes so dense that the process soon stops. The electro-osmosis process was too expensive and could not be installed in a short time. First prize was awarded a filter press apparatus using thin metal discs clamped together as filter plate. Second prize was given to a filter cloth of specially woven paper material. Third prize, porous plates made of porous material, one of coarse grained, another of fine grained structure, usable in ordinary forms of filter presses. Fourth prize, the method of sieving and dry grinding before mixing with a suitable amount of water in a pug-mill. Other methods, some of which are continuous could not be considered because they could not be used for lack of coal. The methods submitted are grouped into eleven divisions. E. N. BUNTING.

9. Ceramic applications of the electrosmosis process. FELIX SINGER. Selb. *Ber. d. Tech. Wiss. Abt. d. Ver. keram. Gewerke.*, **5**, Pt. 5, 16–22 (1919).—A kaolin is obtained by this process of much higher purity than the usual washed kaolin, and its use in a body insures freedom from casting flaws, caused by the impurities, principally mica, in ordinary purified kaolin.

E. N. BUNTING.

10. A sensitive method of thermal analysis, and the transformation points of quartz, of iron, and of nickel. ALBERT PERRIER AND F. WOLFERS. Lausanne. *Arch. sci. phys. nat.*, **2**, 372–81 (1920).—The method employs the differential thermocouple but avoids the necessity of employing a second material as comparison or reference substance. Instead, two samples of the material under investigation are used, being placed at different levels in the furnace so that one lags about 10° behind the other on heating or cooling. Both the differential couple and the temp. couple are connected to a recording chronograph. The method is rapid (20°–60° per min.) and sensitive. The α-β-trans. temp. of quartz was found to be 570°. (Cf. Perrier, *Ibid.*, (4) **46**, 45 (1918). LOUIS NAVIAS.

Refractories and Furnaces

11. Physical characteristics of refractories. I. Spalling losses. II. Cold and hot abrasion tests. M. L. HARTMAN AND O. A. HOUGEN. *Trans Am. Electrochem. Soc.*, **36**, preprint (1920); cf. *C. A.*, **14**, 2246.—I. Comparative tests were made on 12 different kinds of refractory bricks purchased in the open market, exposed to rapid cooling, in an air blast, from a temp. of 1350°. Three of these kinds were completely disintegrated at the 7th, 4th and 3rd treatment. The others were treated 10 times. The three

bonded carborundum varieties showed the least spalling (under 8%). Chrome brick was all gone after the 7th test, silica after the 4th, and magnesia after the third. II. A carborundum cutting wheel was used for the hot and cold abrasion tests and the abrasion in a given time, under equal pressures, noted. Again the bonded carborundum gave the best results. In discussion, it was brought out that this test was probably very much affected by differences in heat cond. W. E. RUDER. (*C. A.*)

12. **Heating of retort settings. Some theoretical considerations in the design of gas works plant.** G. DOUGILL. *Gas J.*, **152**, 454–6 (1920); *Gas World*, **73**, 428–9 (1920).—The vertical retort lends itself most readily to efficient heating, the horizontal retort is most difficult, and the coke oven occupies an intermediate position. The efficiency of the horizontal retort is reduced by the supporting walls, and it is proposed that thinner walls at shorter intervals would produce better heating without diminishing the mechanical strength. In horizontal-retort plants where outside producers are installed, it would be well to follow coke-oven practice and build the retorts in vertical lines and the combustion chambers at each side of the retort with recuperators. J. L. W. (*C. A.*)

13. **The development of the refractories industry in general and especially during the last war.** H. GEYER. MARKTREDWITZ. *Ber. d. Deut. Keram. Gesell.*, **1**, Pt. 2, 33–45 (1920).—Production of ceramic material has doubled since 1900. The present output is about 1,000,000 tons, which is only $^2/_3$ normal. There are one hundred factories and they employ 35,000 workers. 250,000–300,000 tons of coal are used annually. The business statement of the United Chamotte Factory of Marktredwitz, whose annual production is about 25,000,000 kgs. follows: Raw material 15.1%; Coal 9.7%; expense of operating machinery, 4.7%; wages 25.4%; operating expenses, 8.6% sales expenses, 15.8%; of which 5.4% is for salaries; warehouse costs 7.9%; gross profit, 12.8%, total 100%. E. N. BUNTING.

14. **Utilization of the ash from ceramic kilns.** M. SAUER. Augsburg. *Ber. d. Deut. Keram. Gesell.*, **1**, Pt. 2, 48 (1920).—The ash from a kiln fired with a mixture of wood and coal had a heating value of 2120 Cal/kg. and could be used in heating boilers. Slag and dirt must be removed by sieving before use. E. N. BUNTING.

15. **The utilization of heat from cooling kilns.** R. RIEKE. *Ber. d. Deut. Keram. Gesell.*, **1**, Pt. 1, 36–8 (1920).—Fuel can be saved by using the heat from cooling kilns to warm working rooms or drying rooms. A system of pipe lines leads the hot air from the kiln to the rooms and where several kilns are used, a considerable saving in fuel is obtained. E. N. BUNTING.

BOOK

16. WILHELM BORCHERS. **Die elekttischen Oefen.** WILHELM KNAPP. Halle an der Saale, Germany. 1920. 289 pp. 443 illus. 3rd enlarged edition.

PATENTS

17. **Kiln.** FRANCIS FIDLER. U. S. 1,364,090, Jan. 4th, 1921.—A tunnel and a car kiln having a cooling zone and a drying tunnel, the walls of the cooling zone having ducts closed against the zone but with portions open to the heat of the zone of relatively high heat conductivity, and a means of communication between the ducts and the interior of the drying tunnel.

18. **Electrically-heated crucible, melting-pot, and the like.** CHARLES WILLIAM SPEIRS. U. S. 1,366,135, Jan. 18, 1921.—The combination with pourer element, of electrical terminals at each end of the crucible and an electrical terminal fitted to the outer end of the pourer element, from which current can pass through the element to either or both of the main crucible terminals.

19. **Refractory Furnace.** WILLIAM JEFFREY HILL. Montreal, Canada. 1,363,787, Dec. 28, 1920.—A furnace structure comprizing a heat accumulating and radiating element having tortuous passages therethrough by the arrangement of fire-brick transversely and longitudinally, a deflecting slab surmounting the fire-brick centrally and extending longitudinally from end to end, a vertical longitudinal central wall on the slab, brick walls inclosing the element and forming an oven thereabove and having central and side ledges from the interior wall level with the vertical central wall, and a hydrocarbon burner emitting a flame into the oven.

20. **Abrasive and refractory article and method of producing same.** ALBERT H. ANDERSON. U. S. 1,364,849, Jan. 4, 1921.—A combination of matter for forming ceramic articles comprizing refractory or abrasive crystalline grains, a plastic clay, water and an oily lubricating agent.

21. **Surface-combustion furnace.** FRANZ J. DENK. U. S. 1,365,769. Jan. 18, 1921.—A surface-combustion furnace, a chamber, a zone to be heat in the chamber, spaced refractory material at a side of the zone, means dividing the material into a series of sections, separate means for supplying combustible gaseous fuel to the material in each section and separate means for controlling the flow of the fuel to each section and means for drawing the products of combustion away from, and out of contact with, the articles being in the chamber.

22. **Heat resisting cement.** HAROLD S. ASHENHURST. U. S. 1,365,077. Jan. 11, 1921.—A new composition of matter composed of finely divided asbestos having weight of twenty-five to fifty pounds per cubic foot, a water-soluble salt, and water, combined as set forth.

23. **Refractory material.** LOUIS DENIS. Liege, Belgium. 1,365,230. Jan. 11, 1921.—Porous, refractory material consisting of a mixture of pure, rich refractory earth, poor earth, magnesia, and saw dust, heated to a temperature sufficiently high to consume the saw dust and thereby render the product porous.

24. **Refractory article and process for making same.** FRANK J. TONE. U. S. 1,362,274, Dec. 14, 1920.—As a new article of manufacture, a highly refractory material consisting essentially of a burnt mixture of zirconia sillimanite.

25. **Refractory article and process for making same.** OTIS HUTCHINS. U. S. 1,362,317, Dec. 14, 1920.—A shaped highly refractory article formed of a burned mixture containing zirconia and chromide.

26. **Crucible smelting-furnace.** CHARLES M. STEIN. Paris, France. 1,365,204, Jan. 11, 1921.—A crucible smelting furnace particularly intended for the smelting of glass or crystal, having a central gas burner, a crucible chamber arranged centrally above the burner comprizing a series of uniformly spaced hollow arches, a regenerator for heating the air supplied to the burner, flues connecting the regenerator with the hollow arches, and flue openings carried by each arch, opening into the arch flues for establishing a return circuit for the hot flames and gases entering the crucible chamber.

27. **Refractory material and process of making it.** OTIS HUTCHINS. U. S. 1,362,316, Dec. 14, 1920.—As a new article of manufacture, a highly refractory material consisting essentially of a burnt mixture of zirconia and alumina.

C. M. SAEGER, JR.

Chemistry, Physics and Geology of Raw Materials

28. **New modification of silicic acid.** ROBT. SCHWARZ AND OTTO LIEDE. *Ber.*, **53B**, 1680–9 (1920).—By hydrolysis of SiF_4 in boiling water, opaque, non-gelatinous scales were formed which, after dialyzing 8 days, contained 95% water and differed little from the product obtained by hydrolysis of SiF_4 at 0° in appearance or rate of dehydration over H_2SO_4. The chem. conduct of the first (*b*-acid) product was found to be entirely different from that of the second (*a*-acid); 1 g. of the latter with 95% water content dissolved in 1% HF in 9 min., while 1 g. of the former with the same water content required 36 min. The *b*-acid adsorbs practically no methylene blue, while the *a*-acid removes it almost completely from soln. In 5% NaOH the *b*-form showed much lower soly. than the *a*-form, both for water-rich and water-poor prepns. In 3 *N* NH_4OH the Q value did not exceed 25 even in 49 days, and this value was reached only with water-rich, fresh prepns.; aged or water-poor prepns. gave about 15. The *b*-acid is concluded to differ from the *a*-acid in the larger size of the primary particles and in giving, upon soln., a more highly polymerized polysilicate. The analogies between these two forms of silicic acid and the two forms of stannic acid (Mecklenburg, *C. A.*, **6**, 1720) are very marked. Surprisingly, hydrolysis of $SiCl_4$ at 100° gave a product showing all the properties of the *a*-acid and with a value of $Q = 48$ in a gel 14 days old. A. R. MIDDLETON. (*C. A.*)

29. **The dynamics of capillary flow.** EDWARD W. WASHBURN. Univ. of Ill. *Phys. Rev.*, **17**, 273 (1921).—If a porous body behaves as an assemblage of small cylindrical capillaries, then if it be immersed in a liquid, the rate of

penetration, dv/dt, of the liquid into the body is proportional to the square root of the ratio, γ/η, of the surface tension of the liquid to its viscosity and inversely proportional to the time of soaking, t, *i. e.*, the volume, V, of liquid which penetrates the body at the end of the time t, is given by $V = k\sqrt{\gamma/\eta t}$. The theoretical deductions are confirmed by experiments.—Ed.

30. The internal friction of quartz filaments at high temperatures. C. E. Guye and A. Morein. Geneva. *Arch. sci. phys. nat.*, **2**, 351–71 (1920).—With respect to torsional friction fibers of quartz and glass behave differently than those of metals. At low temps. C. E. Guye and M. Einhorn (*Ibid.*, **41**, Apr., May and June, 1916) have shown that the logarithmic decrement (λ) for fibers of quartz and glass is practically independent of the amplitude of oscillation, which is not the case with metal fibers. In the present report, a description and sketch of app. used for quartz threads 23 cm. long are given. The suspended threads were allowed to oscillate, under various conditions and the consecutive amplitudes were recorded photographically. Measurements were made at temps. from 18° to 325°. The authors conclude that the internal structure of quartz changes on annealing in such a way that λ increases (at 20° for fibers 0.580 mm, λ before annealing = 0.00943, after annealing 0.01352). The change of λ with temp. depends upon the diameter of the fiber, the smaller the diameter the higher the temp. of minimum λ (120° for fiber of diameter 0.654 mm., 200° for diameter 0.208 mm.). It was not possible to obtain a "normal state for annealed quartz," *i. e.*, independent of the diameter of thread. It was found that λ is practically independent of the amplitude and of the moment of inertia of the oscillations. It is conjectured that with proper annealing it should be possible to render fibers of all diameters identical as far as structure is concerned. The results for quartz are in general analogous to those obtained for a Jena glass by C. E. Guye and S. Vassileff (*Ibid.*, March and April, 1914). Louis Navias.

31. Arc images in chemical analysis. Wm. Roy Mott. *Trans. Am. Electrochem. Soc.*, **37**, preprint (1920).—A new method of chem. analysis has been formulated, which consists in bringing the materials to be tested into or under the influence of the carbon arc in a special manner. Full details are given. The major analytical resources of this method consist in: (*a*) Characteristic modifications in the appearance and behavior of the arc stream, and of the carbon craters. (*b*) The order of distn. of the materials under the influence of the heat of the arc. (*c*) The character, color, position and form of the distn. deposits upon the upper and lower electrodes, and the character of the residues. Also specific modifications of these appearances by addition of suitable reagents. (*d*) The application of ordinary analytical reactions to the deposits and residues after decompn., distn., or sepn. by the arc. The method has unique advantages in the analysis of all *refractory materials*, minerals and compds. the decompn. of which is most troublesome and tedious by the usual methods of analysis. The method has specific analytical advantages in the case of many of the less common elements, and of those offering

special difficulties by present methods. It is of particular value in the case of the following elements: F, P, Cd, Zn, Ag, Au, Na, K, Ba, Ca, Sr, Mg, B, Be, Al, Ti, Zr, V, U, Cb, Mo, Ta, W, and the rare earth elements. The method is least applicable to the non-metallic elements. It is unavailable for acid radicals and org. compds. The delicacy of test ranges from 1/50 mg. for Ag, Au and W, to 1/10 mg. for S, P, Cd, Pt, Cr, V, Ti, U, Yt, Zr, Th, Cb, Mo, and Ta. Most of the other elements can be detected in amts. of 1 mg. The major constituent of any mineral, alloy, refractory or chem. ppt. can be readily identified in less than 10 min. Distinctive tests and analytical procedure for 65 elements are outlined. C. G. F. (*C. A.*)

32. **The conduct of electrolytic ions in solid bodies. II. Dissociation relations in permutite.** A. GÜNTHER-SCHULZE. *Z. Elektrochem.*, **26**, 472–80 (1920); cf. *C. A.*, **14**, 678.—The electrolytic cond. and the change in mol. vol. of K-Cd, K-Pb, Li-Cd and K-Cr permutite mixts. have been measured. (*C. A.*)

33. **Economic minerals of Madagascar.** GEORGE F. KUNZ. *Eng. & Min. J.*, **111**, 14–18 (1921).—The widespread *graphite* deposits occur in crystalline schists which have been superficially altered to a lateritic clay. The graphite is of excellent quality and being free from sulfides and $CaCO_3$, is suitable for crucibles. The production reached a maximum of 35,000 metric tons in 1917 but since then has dropped. At present graphite having a 80% carbon content is quoted at 850 fr. per ton in Marseilles. *Corundum* also occurs in these lateritic clays. Gem material is rare but there is a considerable production of material for abrasive use. Production started in 1910, and in 1919, 812 metric tons were exported. It is estimated that a production of several thousand tons can be developed. The price is quoted as 750 to 800 fr. per metric ton in Marseilles. There are also notable deposits of *zircon. Zircon* crystals 15 cm. long have been found. D. D. SMYTHE.

34. **Biennial report of the state geologist of Missouri.** H. A. BUEHLER. Rolla, Mo. (1919), 17–20, 42–50, 79, and 96–97.—*Flint clays* have been worked in Mo. for over 50 years and are still being produced over a large area. They form basin shaped deposits and associated with them is a subordinate amount of bond clay resulting from the decomposition of the flint clay. A more recent discovery is *diaspore clay*, an aluminum rich variety, formerly discarded becaues of its sandy texture and tendency to warp when fired. In some cases it is found associated with the flint clay. Although rich in alumina it is poor in silica, lime, and magnesia and appears to be formed of oölites of the mineral diaspore. Besides being added to refractory clays to increase the alumina content it is being used as an ore of aluminum or treated to form an *abrasive*. The deposits are large but have not yet been fully explored. Most of the clay mined in Mo. is *fire-clay* of which some is plastic but much is flint clay. Small amounts of *kaolin*, pottery and brick clays are also mined. The total production in 1917 exceeded that of former years and consisted of 496,694 tons valued at $1,386,338. Of this amount approximately 99% in

weight and 94% in value was fire-clay. Mo. is one of the leading producers of *glass sand*. The sand, which is obtained exclusively from the St. Peter sandstone at a number of places in the state, is remarkably pure, unwashed samples showing 99.14% silica and only 0.078% ion oxide. The Ill. *tripoli* deposits extend south into Mo., for a short distance where they have been worked to a slight extent. An impure *dolomite* is also used as an abrasive, being powdered and used in scouring soap, tooth powder, etc. D. D. S.

35. **High grade talc for gas burners.** J. S. Diller, J. G. Fairchild, and E. S. Larsen. *Econ. Geol.*, 15, 665–674 (1920).—Talc is fire and acid proof. Only the very pure homogenous variety is useful for gas burner tips and electric insulators. The annual consumption is less than 1000 tons and since the U. S. is deficient in the high grade material most of it has to be imported from Italy, France, Germany, and India, the Italian and French deposits being the most important. The high grade talc occurs usually in metamorphic limestone but a small amount is found in altered basic igneous rocks while the German deposits form a third type. The only two domestic deposits of commercial size are (1) in Hewitts, Swain Co., North Carolina where the talc occurs as lenses in metamorphic limestone and has been worked but little in recent years; and (2) near Dublin, Harford Co., Maryland, where the talc occurs in an altered dike of basic igneous rock. During the war this was the chief source of supply but the talc is inferior to the imported material. It is quarried in open pits by the Harford Talc Company. The highest grade imported talc comes from Germany. Much of the Italian talc is not massive enough for gas burner tips but it is remarkable for its purity and so is used for toilet powder. French talc comes from the Pyrenees and was the original source of "French chalk." The talc of India is inferior only to that of Germany for gas burner tips, but is not imported directly. A table is given showing the chemical composition of foreign and domestic talcs. All talc used commercially has some admixed chlorite. Too much chlorite causes the burner to crack and shrink due to loss of water, and to darken and become more porous due to the iron content. The texture and grain are of great importance, the German talc having a scarcely perceptible microscopic grain while the others are distinctly grained. D. D. Smythe.

36. **Flint problems.** C. Carus-Wilson. *Geol. Mag.*, 57, 474–5 (1920).—A number of English flints are described, and attention is called to problems of their origin. S. G. Gordon. (*C. A.*)

37. **High-grade silica materials for glass, refractories, and abrasives.** R. J. Colony. *N. Y. State Museum Bull.*, Nos. 203–4, 29 pp. (1919).—The siliceous formations exposed in New York State have been studied with a view to det. how far the demand for siliceous materials could be satisfied from these deposits. *Glass sand* suitable for common glass occurs in the region of Oneida Lake in relatively small deposits. *Sandstone* of sufficient purity for glass making and easily crushed, occurs near Johnstown (Potsdam) and at Oris-

kany Falls (Oriskany). *Quartzite* with a firmly interlocking structure and of sufficient purity (95–99% SiO_2) for refractories occurs in large quantities in Duchess County (Ponghquag) and near Accord (Shawangunk). Most of the deposits contain rock suitable for use in the manuf. of ferrisilicon. The harder quartzites (Ponghquag) appear suitable for tube-mill liners. No actual tests were made except a few tests for hardness and toughness. Chem. analyses of the various deposits are given and numerous photomicrographs of thin sections. J. S. LAIRD. (*C. A.*)

38. **Measurement of vapor pressures of certain potassium compounds.** DANIEL D. JACKSON AND JEROME J. MORGON. Columbia Univ. *J. Ind. Eng. Chem.*, **13**, 110 (1921).—By means of the dynamic method using a current of N_2, the following vapor pressures in mm. of Hg were found: KOH, 8 (795°), KCl, 1.54 (801°), 8.33 (948°), 24.1 (1044°); K_2O, from K_2CO_3, 1.68 (970°), 5.0 (1130°); K_2SO_4, 0.4 (1130°). Up to 1335° the silicates *leucite, orthoclase*, and *glauconite* gave no appreciable vapor pressure. The results will be applied to the problem of *potash recovery* from *cement* kiln gases. Ed.

Whiteware and Porcelain

39. **Statement to the Color Committee (of A. O. C. S.).** I. G. PRIEST. *Cotton Oil Press*, **4**, No. 6, 45–7 (1920).—A brief statement of the elementary ideas on which colorimetry as a science is based including definitions for color, hue, satn., brilliance, light, homogeneous light, transmission, transmittance, and transmissivity. H. S. B. (*C. A.*)

40. **Porcelain insulators.** O. BOUDOUARD. *Rev. gén. élec.*, **1920**, 681–6; *Science Abstracts*, **23B**, 342.—Tests on 31 samples of American, French and German makers, from various transmission companies are discussed. Six tables give their types and characteristics, chem. analyses, compn. referred to SiO_2 as 100, aspect of fracture and physical appearance, cause of failure, and explanation of defective performance. Compn. varied widely: SiO_2, 63.3 to 74.5%; Al_2O_3, 20.5 to 29.8; CaO, where intentionally present, 1.9 to 4.0; alkalies 3.2 to 6.5; the variations are more striking referred to SiO_2 = 100. Defective specimens were high in SiO_2 or CaO. Since quartz is piezo-electric and feldspar liable to electrolysis, substitution should be made with sillimanite, kaolin, alumina or zirconia, and with Al, Mg, Be or alk. silicates, resp. This development has been made by American ceramists, who adhere most closely to Watts' porcelain formula: $RO.4Al_2O_3.16SiO_2$. Close attention to these results appears profitable. F. H. H. (*C. A.*)

41. **Factors controlling the design and selection of (porcelain) suspension insulators.** W. D. A. PEASLEE. *J. Am. Inst. Elec. Eng.*, **39**, 571–9 (1920).—The factors governing rational porcelain insulator design and insulator shape as affected by the dielec. field of force are discussed. The development of a rationally designed suspension insulator, its proper testing, and its operating

characteristics with a discussion of possible future progress is also described. Curves showing potential distribution, impulse ratio, puncture voltage and flash-over are given. W. E. RUDER. (*C. A.*)

42. **Testing (porcelain) insulators in factory and field.** LESLIE N. CRICHTON. *Elec. J.*, **17**, 506–10 (1920).—Description of standard methods. C. G. F. (*C. A.*)

43. **Surface leakage as a factor in (porcelain) insulator design.** T. M. FEDER. *J. Am. Inst. Elec. Eng.*, **39**, 803 (1920). C. G. F. (*C. A.*)

44. **Experience with porcelain insulators in America.** F. W. PEEK, JR. *Elec. World*, **76**, 1061–4 (1920).—8 illus. A full discussion of tests on and the behavior of porcelain insulators. C. G. F. (*C. A.*)

45. **Features of European (porcelain) insulator testing practice.** B. SCHAPIRA. *Elec. Rev.*, **77**, 721–4 (1920); 8 illus. C. G. F. (*C. A.*)

46. **Some physical properties of white ware glazes.** REINHOLD RIEKE. Charlottenburg. *Ber. d. Tech.-wiss. Abt. d. Ver. Keram. Gewerke.*, **5**, Pt. 5, 8–15 (1919).—R. discusses the relative importance of the coef. of expansion, modulus of elasticity, and tensile strength in glazes. Although insufficient data are available, it is likely that elasticity and tensile strength are as important as thermal expansion. While the coef. of exp. of technical porcelain up to 700° is about 35×10^{-7}, that of white ware bodies averages 100×10^{-7}, and a value of $50–100 \times 10^{-7}$ is given for several white ware glazes. The modulus of elasticity for several glazes varies from 5700 to 6800 kg./sq. mm., while the tensile strength is 5–8 kg/sq. mm. The best glaze is one having the highest tensile strength and elasticity, and the same coeff. of exp. as the body. E. N. BUNTING.

47. **Sharp fire colors for porcelain.** W. FUNK. Meissen. *Ber. deut. Keram. Ges.*, **1**, Pt. 1, 24 (1920).—This article is a general survey of the subject with particular reference to practice as related to hard porcelain. The author discusses the production of the colors blue, yellow, brown, red, black, green and violet; the use of colorless ingredients in the production of colors; the organic materials which are employed as mediums in the application of the colors; and finally, briefly, the various processes for the prepn. of the colors. Brief reference is made to the use of some of the rarer materials, such as neodymium phosphate for violet, tungstic acid with iron and manganese for browns, praseodymium phosphate for light transparent greens, and the doubtful value of neodymium oxide and tungstic acid for underglaze red colors. Only general principles are given, with no formulae or recipes. The paper is an interesting summary but contains no new contribution. C. W. P.

48. **Normal colors and harmony of colors.** W. OSTWALD. *Keram. Rudn.*, **28**, 447 (1921).—Ostwald's theories are more fully discussed in his book Die Farbenlehre. Leipsig: Verlag Unesma. 259 pp. Outline comment on the fundamentals of his new laws of color which are claimed to systematize the

innumerable color possibilities and permit of classification. Statement by the Director of the Meissen Porcelain Works that they have used O.'s tables for some time for the preparation of harmonic colors successfully.

WM. H. CLARK.

49. **Surface creepage and high-voltage (porcelain) insulation.** T. NISHI. *J. Am. Inst. Elec. Eng.*, **39**, 949–59 (1920). (*C. A.*)

50. **The decoration of porcelain.** BANARD, H. *Pottery Gaz.*, **46**, 85–91 (1921).—True oriental porcelain is fired in the first firing only sufficiently to enable it to be handled and the hard firing takes place during the glost firing. In the case of hard porcelain and common stoneware the body and glaze are fired in one operation whereas soft porcelain, china, English bone china, and earthenware undergo two firings. Motor driven polishing lathes are used to remove blemishes from glazed ware due to stilt marks, etc. Underglaze colors when examined under the microscope appear as fine powder. In printing a copper plate is engraved with a pattern which is then covered with an underglaze color. The surplus color is rubbed off. A piece of tissue paper sized with a water size is spread over this plate and the color is pressed onto the paper with a lithographers press. The design is then transferred to the bisque ware which is then passed through a hardening-on kiln where it is fired just sufficient to harden the color. The glaze is then put on and it is fired in a glost kiln. Overglaze colors are a mass of glass with metallic oxides differing from underglaze colors which contain no flux. For enamel colors certain metals may be used. Gold gives a pink and manganese gives an amethyst. Copper with a high soda glass gives turquoise and with a high lead glass, bottle green. The best gold decorations are made by grinding metallic gold with mercury. A flux of glass is used with the gold to make it adhere more firmly. In acid gold decoration the pattern is put on white glazed china with an oily acid resisting paint. The piece is then plunged in an HF bath where all exposed portions are partly etched by the acid. The paint is then removed and gold decorations applied all over the ware. After firing the piece is burnished whereupon the pattern appears bright and the etched portion dull. Ground laying is a process by which an even coating of color is applied on ware in whatever space is desired. For example a green vase with white panels is made as follows: The shape of the panels is painted on with resist. color—anything that will resist oil—which may be a mixture of treacle and color. A very sticky oil, such as boiled linseed, is then applied over the pot. Green enamel is then dusted on, there is just sufficient oil to take a certain amt. of enamel and no more, thus producing an even tone. The pot is then immersed in water which removes the treacle and color but not the oil and enamel

H. G. SCHURECHT.

Brick and Tile

PATENTS

51. **Brick and process of making the same.** FRANK ORTH. U. S. 1,363,264, Dec. 28, 1920.—The process for the manufacture of building material which

consists in first preparing an aggregate comprizing particles of substantially pure sillica material in sizes graduated from those of relatively large size to those which will pass a forty mesh screen and of such proportions as to secure a minimum percentage of voids, then mixing therein 2–5% of calcined and hydrated lime, then molding the mixture into the desired shape, then subjecting the material so molded to the action of steam at substantially 125 pounds per square inch for approximately ten hours, and directly thereafter burning the same for a period of substantially eight days at a temperature of 2800–3000°F.

52. **Brick-making machine.** ARTHUR O. DUPUY. U. S. 1,363,853. Dec. 28, 1920.—The combination of a suitable frame; a plugging mill mounted upon the latter; a suitable die beneath the mill; a pressure chamber located intermediately of the mill and die; a horizontally mounted plunger rod and a plunger connected therewith, the plunger coöperating with the pressure chamber to force the contents of the latter into the die, the plunger including a stepped member; means for shifting the stepped member transversely with reference to the direction of movement of the plunger rod, the means including an elongated bearing rod secured to the stepped member a shaft pivotally mounted upon the frame, an arm fixed to the shaft and provided at its free end with a fork adapted slidably to engage the elongated bearing rod, and means for actuating the shaft; means for feeding the contents of the plugging mill to the pressure chamber; a crank shaft mounted on the frame and connected with the plunger rod; and suitable gearing for actuating the crank shaft.

53. **Mold for making tiles.** GEORGE W. VOUGHT. U. S. 1,365,753, Jan. 18, 1921.—A mold for shaping hollow tiles comprizing a box having side and end sections, an elastic rubber lining secured to the sections, and a plurality of cores each having an elastic rubber cover arranged in the mold.

54. **Brick-mold.** ROBERT A. FONTAINE. U. S. 1,361,148, Dec. 7, 1920.—A device comprizing a frame, consisting of parallel side and end angle bars forming a mold, parallel wires connecting the side bars, parallel wires connecting the end bars, means on the bars adjustably supporting the ends of the wires, the means comprizing wedge-shaped blocks having wire receiving slots therein, and cross pieces secured to the wires and located on the inclined upper faces of the wedge blocks.

55. **Hollow building-tile.** LEE B. GREEN. U. S. 1,365,825, Jan. 18, 1912.—In a hollow building tile which is rectangular in plan, a portion centrally of the tile and four diagonal partitions extending from the different corner portions respectively of the tile toward the central portion and from top to bottom of the tile, the tile having the partitions, upon laying the tile on adjacent portions of two longitudinally alined tiles which correspond with the superposed tile, arranged to extend transversely of and rest on diagonal partitions of the alined tiles.

56. **Floor for brick-kilns.** HALVER R. STRAIGHT. U. S. 1,364,155, Jan. 4, 1921.—A floor block having its top and bottom substantially parallel and its ends beveled upward and inward, one side being provided with a vertical groove or recess. C. M. SAEGER, JR.

Glass

57. **Glass manufacture and the glass sand industry (of Pennsylvania).** C. R. PETTKE. *Topographic and Geol. Survey of Penna.*, Rept. 12, 278 pp. (1919).—P. has made extensive field study of the glass sand deposits and workings in Penna. The more important central deposits are in the Orishany sandstone, the western in the Pottsville. The Tuscarora sandstone is a hard quartzite which can not be economically crushed to glass sand. The Oriskany deposits are believed to have been derived from the Tuscarora and their purity is attributed to this origin. They are often very pure but in all cases washing is necessary to produce No. 1 sand. Only weathered portions of the deposits are workable, the unweathered being hard quartzite. The report is extensively illustrated and includes a detailed description of glass manuf. including the more recent developments, such as machine-blown glass.

J. S. LAIRD.

58. **Colored glass.** K. WARGA. Brit. 148,304, July 9, 1920.—Colored designs are formed on glass surfaces by fusing the colors on at one operation. The designs are formed of fusible mineral colors and are built up in successive layers on transfer paper. The complete design is then transferred to the glass surface and fired at a gradually increasing temp. until it is completely fused on. The layers are composed of materials which melt at successive temps., the layer next the glass melting first and the outer layer last. The temp. at which the last layer melts is about 100° below the m. p. of the glass.

(C. A.)

59. **Glass, enamels, and glazes.** E. REITZ. Brit. 148,816, July 10, 1920.—Relates to the manuf. of white clouded glass, enamels, and glazes. Fluorides are used in conjunction with compds. of Zr, Sn, Be, etc. Alkali fluorides, alkali silicofluorides, CaF_2, and cryolite are stated to be suitable compds. for use. A frit, given as an example, consists of Na_2CO_3, feldspar, quartz, natural zirconia and sodium silicofluorides. The F. compds. are used in larger proportions than has hitherto been done. The batches must contain a large proportion of SiO_2. *(C. A.)*

60. **The devitrification of glass. A surface phenomenon. The repair of crystallized glass apparatus.** ALBERT F. O. GERMANN. Western Reserve Univ. *J. Amer. Chem. Soc.*, 43, 11–14 (1921).—Due to the hydrolytic action of adsorbed moisture, the surface of weathered glass contains silicic acid and also alkali and alkaline earth carbonates. Washing removes the carbonates. Heating dehydrates the silicic acid and gives a rough surface. The sepd. silica may gradually dissolve in the underlying glass or may unite with the

lime forming a difficultly fusible cryst. Ca silicate over the surface. Weathered glass which devitrifies and becomes brittle when worked in the flame can be made practically as good as new glass, if the devitrified surface layer be removed by washing with dil. HF before heating the glass in the flame. Ed.

61. **Composition of Golden Yellow Glass.** *Schnurpfeil's Review for Glass Works*, **4**, 745 (1921).—Sand 100, potash 10, soda ash 30, lime 17, millet 2.5, bark 0.75. R. J. MONTGOMERY.

62. **Opal Glass for Tubing.** *Schnurpfeil's Review for Glass Works*, **4**, 747 (1921).—Sand 100, soda ash 38, lime 10, alumina 6, feldspar 15, fluorspar 13, lime oxide 2. R. J. MONTGOMERY.

63. **Absorption of heat in glass.** A. Q. TOOL AND C. G. EICHLIN. *J. Optical Soc. Am.* **4**, 340–63 (1920); cf. *C. A.*, **14**, 2245.—A marked increase in the absorption of heat by glass heated at a uniform rate takes place within a narrow temp. range slightly above the annealing temp. The authors suggest as the cause of the formation of one or more types of mol. aggregates possibly of cryst. structure. Tests on chilled and annealed glass produce the results expected from this theory and also lead to the possibility, "that *annealing* is not alone a question of removing stresses, but also of producing homogeneity." The results of various tests on 20 types of glass are tabulated.

DONALD E. SHARP (C. A.)

64. **Making of aventurine glass.** *Schnurpfeil's Review for Glass Works*. **4**, 723 (1920).—Copper aventurine is a reddish brown, gold-spangled composition while chrome aventurine is greenish brown, gold-spangled. Melting procedure is as follows: After melting in an open pot, it is often covered with a lid and kept in the furnace for a certain time thus closed. The whole pot is then placed in a hot annealing furnace and cooled slowly allowing the copper and chrome crystals to form. Batch for red aventurine: Sand 100, soda ash 40, lime 15, lead 5, borax 5, oxide of tin 2, ferrous oxide 4, red oxide of copper 8.5 Green aventurine: Sand 100, soda ash 36, lime 14, fluorspar 2, barytes 14, potassium bichromate 9.5. ROBERT J. MONTGOMERY.

65. **Composition of selenium red glass.** *Schnurpfeil's Review for Glass Works*, **4**, 725 (1920).—Sand 100, soda ash 35, lime 20, fluorspar 1, selenium 0.5, arsenic 1.5. ROBERT J. MONTGOMERY.

66. **A new electrical precipitation treater.** (**The electrical conductivity of glass**). M. SHIBUSAWA AND Y. NIWA. Electrotechnical Laboratory, Tokyo. *J. Am. Inst. Elec. Eng.*, **39**, 890–903 (1920).—The new precipitation treater for the Cottrell process consists of a metal tube as the passive electrode and a *glass covered* coaxial wire as the active electrode. Since it became evident from the action of the new treater that a current was passing through the glass, the authors investigated the *variation of the resistivity of glass with temperature*. A soda lime glass tube filled with mercury, wrapped with tinfoil

and supplied with guard rings to prevent surface leakage was used. For applied voltages below 500 volts the resistivity, $\overline{R}$, between 20° and 80°C was found to be $3.28 \times 10^9 \times t^{-3.25}$ and for an applied voltage of 10,000, $2.06 \times 10^9 \times t^{-3.25}$ megohms. *Effect of potential gradient.* The relation found was $\overline{R} = 2.9 \times 10^9 \times V^{-2.60}$ megohms, where V is in *kv*; room temperature. The soda-lime glass showed hysterisis while Jena glass showed none. Ed.

67. **The permeability of glass to iodine and bromine vapours.** James Brierley Firth. *Jour. Chem. Soc. Lond.*, **117**, 1602–3 (1920).—Iodine and bromine do not diffuse through glass under ordinary experimental conditions. Only in extreme cases is there a possibility of such diffusion. After a period of nine and one-half years, iodine was found to have passed through a glass bulb 0.208 mm. thick. The bulb was heated to 360°C for 100 days during the experiment. In this experiment the bulb was placed in a large tube and both tube and bulb evacuated. In another case, in which iodine was found to pass through 0.211 mm. of glass, there was a vacuum outside of the bulb and atmospheric pressure inside. There was no evidence of bromine passing through a similar thickness of glass after nine and one-half years. J. L. C.

PATENTS

68. **Glass stirring machine.** Charles R. Hazel. U. S. 1,361,853, Dec. 14, 1920.—In combination a supporting frame for glass cylinders, a plurality of arms spaced along the frame and extending transversely thereof, and a flexible equalizing means extending longitudinally of the frame and supporting the series of arms.

69. **Glass and its manufacture.** Louis E. Barten. U. S. 1,362,917, Dec. 21, 1920.—As a new article of manufacture, normally detached glass-ware of definitely predetermined configuration, and consisting of a throughout uniform, homogeneous, mass of uniformly-light-effected glass containing not less than 25 per cent, of titanic oxid.

70. **Glass annealing leer.** Edwin E. Milner. U. S. 1,361,604, Dec. 7, 1920.—An annealing furnace comprizing a plurality of groups of chamber heating flues surrounding the major portion of the annealing chamber in which the articles are to be annealed, one group of the chamber heating flues having means for circulating a heating medium therethrough in opposite directions in adjacent flues, and another group of the chamber heating flues having means for circulating a heating medium upwardly in the same direction in adjacent flues at opposite sides of the annealing chamber, substantially as described.

71. **Machine for casting plate-glass.** Harry O. Bisbing. U. S. 1,363,450, Dec. 28, 1920.—A reservoir adapted to contain molten glass, a discharge passageway leading from the reservoir, a chain-like series of platens adapted to receive glass from such discharge passageway, means for bringing each platen in place to receive glass, a flap valve closing the discharge passageway opened

by each platen successively as the same is brought into receiving position, means for closing the flap valve after such platen has passed from its receiving position, and a tamping plate adapted to be brought into contact with the glass carried in each platen, leveling and smoothing the same.

72. **Glass-handling apparatus.** THEODORE C. STEIMER. U. S. 1,362,756, Dec. 21, 1920.—A machine for treating glass articles, with continuously traveling article handling mechanism, of a fixed station, a transfer mechanism movable with and in respect to the article-handling mechanism, device for moving the transfer mechanism to and holding it at the fixed station and moving it with the article-holding mechanism and in coöperative relation therewith and device for effecting a transfer of articles between the transfer mechanism and the station while the transfer mechanism is stationary.

73. **Process of obtaining mold charges of glass and apparatus therefor.** ENOCH T. FERNGREN. U. S. 1,362,785, Dec. 21, 1920.—The process of obtaining glass mold charges which consists in causing glass to issue from a suitable outlet, and while moving under gravity to sever into charges and imparting to the severing means, while severing, a movement having a component in the direction of the movement of the glass at the severing point.

74. **Glass-drawing process.** HARRY G. SLINGLUFF. U. S. 1,364,895, Jan. 11, 1921.—The process of drawing a glass sheet from a relatively large deep body of molten glass, which consists in segregating the layer of glass beneath the line of generation of the sheet from the main body of glass there beneath and drawing the sheet upward with such line of generation remote laterally in both directions from any anchoring or chilling body of clay or refractory material in the body of glass.

75. **Apparatus for drawing glass cylinders.** ARTHUR E. SPINASSE. U. S. 1,361,635, Dec. 7, 1920.—In combination, a bait, a drawing drum connected to the bait, a motor for driving the drum, an air conduit connected to the bait, a blower for supplying air to the conduit, and means whereby the blower may be connected to and driven by the motor.

76. **Process for manufacture of white clouded glasses, enamels, and glazes.** EDUARD RIETZ. U. S. 1,366,101, Jan. 18, 1921.—The process which comprizes the embodying unpurified clouding material in the glass, glaze or enamel with material containing sufficient fluorin to prevent discoloring.

77. **Machine for burning or glazing the edges and sides of glassware.** ALBERT BREAKENRIDGE KNIGHT. U. S. 1,364,939, Jan. 11, 1921.—A device of this type having a rotatable gear, a gear fixed against rotation mounted above the rotatable gear coaxial therewith; means for simultaneously vertically adjusting the gears, spindle journals secured to the rotatable gear, rotatable spindles mounted in the journals, pinions on the spindles meshing with the gear fixed against rotation, and rollers rotatably carried by the spindle journals and engaging the upper surface of the last named gear.

78. **Machine for grinding glassware.** ALBERT BREAKENRIDGE KNIGHT, U. S. 1,364,940, Jan. 11, 1921.—An apparatus for grinding glassware with a support, a plurality of elements for holding and rotating grinding members. a plurality of chucks for receiving the articles to be ground and connected with the support to be moved toward and away from the grinding members, with means to successively move the chucks in one direction, embodying treadle levers corresponding in number and arrangement to the chucks, and a system of levers connecting each of the treadle levers and its corresponding chuck.

79. **Glass gathering and shaping machine.** MICHAEL J. OWENS. U. S. 1,364,514, Jan. 4, 1921.—The combination of a gathering device, a press plunger, a press mold, means to relatively reciprocate the plunger and mold to and from each other, and means to introduce the gathering device between the plunger and mold while they are separated and discharge a gather into the mold.

80. **Glass.** MAURICE A. SMITH. U. S. 1,365,797, Jan. 18, 1921.—A glass having a low coefficient of expansion and high resistance to high and low temperatures, the glass being made from a batch consisting of a prepondrance of silica, smaller amounts of boric oxid, alumina, sodium nitrate and sodium carbonate, and still smaller amounts of calcium carbonate and arsenic trioxid. C. W. SAEGER, JR.

Enamel

81. **Gas in the enameling industry.** J. H. GUMZ. *Gas Record*, Dec. 22, 1920.—Reprinted by Surface Combustion Co., New York. Vitreous enamels are differentiated from japan varnishes and a historical sketch of the industry is given together with a brief description of the enameling process. The author emphasizes the necessity of a muffle type furnace with coal as fuel, or even with gas or oil when the surface combustion or intermittent firing plan is not used. Cross section views of the various types of furnaces are shown. The muffle type furnace especially where coal is the fuel, shows highest construction and repair costs and requires the most floor space. Firing costs of the various types of furnaces are as follows per cu. ft. of oven space heated per hr.:

Type of Furnace	Cost per hour Without Recuperation	Cost per hour With Recuperation
Direct fired gas	1.0 cent	0.8
Semi muffle gas	1.4	1.1
Oil fired (prob. muffle type)	1.5	1.2
Full muffle gas	1.6	1.2
Coal fired muffle	1.7	1.3
Electric direct	...	1.4

Further savings result from applying flue gases in waste heat boilers and dry rooms. Some of the advantages claimed for the direct fired gas furnace are: (1) lower operating costs; (2) low construction costs because muffles,

stacks and excessive insulation are not required; (3) low repair costs; (4) elimination of coal and oil storage and fireman; (5) uniform heating and larger percentage of furnace available for firing ware; (6) absolute control and ability to rapidly change furnace temp. as required; (7) increased output considering time lost during repairs and the higher temp. possible. R. R. DANIELSON.

PATENTS

82. **Enameling resistance units.** LEONARD KEBLER. U. S. 1,361,869, Dec. 14, 1920.—The method of enameling tubular units which consist in applying enamel material on them, and heating them electrically from within.

83. **Process for producing a single white-enamel coat on steel.** SIMON RIESSER. U. S. 1,360,317, Nov. 30, 1920.—In the treatment of frit in the production of white enamel on steel, the process of grinding the frit with water and clay and removing a portion only of the soluble enameling constituents.

84. **Process for making enamels.** GEORGE RUPPRECHT. U. S. 1,360,585, Nov. 30, 1920.—The process consists in subjecting the raw materials to the direct action of a flame developing a high temperature under conditions which prevent the material melted thereby from coming in contact with foreign substances and supporting the molten material upon an unmolten mass of the raw materials. C. M. SAEGER, JR.

Cement, Lime and Plaster

85. **Molding, gypsum cement, etc.** A. HAENICKE. Brit. 148,797, July 10, 1920.—In the production of small shaped articles, *e. g.*, buttons, from gypsum, cement, etc., the finely ground material is pressed in a dry state, the pressed article is removed from the mold and subjected to a spray of H_2O or setting liquid until just sufficient liquid for setting has been absorbed. Burnt magnesite may be employed, a lye of $MgCl_2$ being employed as a setting liquid. (*C. A.*)

86. **Further discussion of "Cal."** S. W. STRATTON. *Concrete* (*Mill Sec.*), **17**, 125 (1920).—Cal is obtained by grinding the dried or undried product resulting from a mixt. of either quicklime or hydrated lime, $CaCl_2$ and H_2O. It can be used to advantage to hasten the set of portland cement. Five % of cal added to a cement mortar increases the strength test at 2 days from 40 to 140%. It has the advantage over $CaCl_2$ in that it is less hydroscopic and can therefore be more easily handled. J. A. MONTGOMERY. (*C. A.*)

BOOKS

87. MÜLLER. **Der Schachtofen in der Zementindustrie.** Charlottenburg: Zementverlag G. m. b. H. 68 pp. M. 5.50. For review see *Tonind.-Ztg.*, **44**, 1073 (1920). (*C. A.*)

88. BLOCK, BERTHOLD. **Das Kalkbrennen im Schachtofen mit Mischfeurung.** Otto Spamer, Leipzig. 240 pp. For review see *J. Fabr. Sucre*, **61**, No. 34. (C. A.)

ACTIVITIES OF THE SOCIETY

Annual Meeting of New England Section

The Annual Meeting was held at Boston, January 22, 1921. Thirteen members attended.

In the afternoon, the Agassiz Museum at Harvard University was visited. One of the most interesting things observed was the exhibit of glass flowers.

A dinner was served at the Engineers Club at 5 P.M., which was followed by a short business session. The following officers were elected for the ensuing year:

Chairman, A. T. Malm.

Councillor, M. C. Booze

Secretary and Treasurer, S. F. Walton.

Executive Committee, Browne Harding, Prof. C. L. Norton.

The following talks were given:

"Some Troubles Encountered in the Manufacture of Watch Dials," by F. P. Flagg, Chief Chemist, Waltham Watch Co.

"Notes on Efficiency of Clay Crucibles," by H. W. Richter of Garhart Dental Specialty Co.

"A Novel Testing Furnace," by S. F. Walton, Kalmus, Comstock & Wescott Co.

"Application of Pyrometers to Ceramic Industries," by H. Goldsen, General Sales Manager, Wilson-Maeulen Co.

The talks were interesting and a lively discussion followed.

M. C. BOOZE,
Secretary New England Section.

JOURNAL AMERICAN CERAMIC SOCIETY

Preparation of Abstracts

Every article in THIS JOURNAL is to be preceded by an abstract prepared by the author and submitted by him with the manuscript. The abstract is intended to serve as an aid to the reader by furnishing an index and brief summary or preliminary survey of the contents of the article; it should be suitable for reprinting in an abstract journal so as to make a reabstracting of the article unnecessary. The abstract should, therefore, **summarize all new information completely and precisely.** Furthermore, in order to enable a reader to tell at a glance what the article is about and to enable an efficient index of its subject matter to be readily prepared, the abstract should contain **a set of subtitles** which together form a **complete and precise** index of the information contained in the article. This requires at least one and often several subtitles even for a short abstract.

In the preparation of abstracts, authors should be guided by the following rules, which are illustrated by the abstracts in THIS JOURNAL for February and March, 1921.* The **new information** contained in an article should first be determined by a careful analysis; then the subtitles should be formulated; and finally the text should be written and checked.

Rules

1. **Material not new** need not be analyzed or described in detail; a valuable summary of a previous work, however, should be noted with a statement indicating its nature and scope.

2. **The subtitles should together include all the new information**; that is every measurement, observation, method, improvement, suggestion and theory which is presented by the author as new and of value in itself.

3. **Each subtitle should describe the corresponding information so precisely** that the chance of any investigator being misled into thinking the article contains the particular information he desires when it does not, or vice-versa, may be small Such a title as "A note on blue glass," for example, is evidently too indefinite a description of information regarding "Absorption spectra of glass containing various amounts of copper-cobalt and chromium-cobalt." General subtitles, such as "Purpose" and "Results" should not be employed as they do not help to describe the specific information given in the article.

4. **The text should summarize the authors' conclusions and should transcribe numerical results of general interest,** including those that might be looked for in a table of physical and chemical constants, with an indication of the accuracy of each. It should give all the information that anyone, not a specialist in the particular field involved, might care to have in his note book.

5. **The text should be divided into as many paragraphs** as there are distinct subjects concerning which information is given, but no more than necessary. All parts of subtitles may be scattered through the text but the subject of each paragraph, however short, must be indicated at the beginning.

6. **Complete sentences** should be used except in the case of subtitles. The abstract should be made as readable as the necessary brevity will permit.

7. The ms. of all abstracts must be typewritten and double or triple spaced.

* The rules were prepared by the Research Information Service of the National Research Council. The Society is indebted to Dr. G. S. Fulcher of the Corning Glass Works (formerly with the National Research Council) for the rules and the illustrative abstracts.

AMERICAN CERAMIC SOCIETY

OFFICERS, 1921-1922

CORPORATION MEMBERS, 1920-1921

Abrasive Company.
Aexander Hamilton Inst.,
American Dressler Tunnel Kilns, Inc.
American Emery Wheel Works.
American Encaustic Tiling Co.
American Terra Cotta & Ceramic Co.

Bausch & Lomb Optical Co.
Beaver Falls Art Tile Co.
Benjamin Electric Mfg. Co.
Bird and Company
Brick and Clay Record.
Buckeye Clay Pot Co.
W. G. Bush and Co.

Canton Stamping & Enameling Co.
Carborundum Co.
Champion Ignition Co.
Colonial Co.
Consolidated Window Glass Co.
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Cortland Grinding Wheel Co.

H. L. Dixon Co.
B. F. Drakenfeld & Co., Inc.
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East Liverpool Potteries Co.
Edgar Plastic Kaolin Co.
Edward Ford Plate Glass Co.
Elyria Enameled Products Co.
Findlay Clay Pot Co.
Foote Mineral Co.

French China Co.
Frink Pyrometer Co.
Gillinder Brothers.
Golding Sons Co.
The Glass Worker.

Hall China Co.
Hanovia Chemical & Mfg. Co.
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Homer Laughlin China Co.
L. J. Houze Convex Glass Co.

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Jeffery-Dewitt Co.
Johnston Brokerage Co.
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Edwin M. Knowles China Co.
Knowles, Taylor, and Knowles Co.
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Lindsay Light Co.
Los Angeles Pressed Brick Co.
Louthan Manufacturing Co.

Macbeth-Evans Glass Co.
Maine Feldspar Co.
F. Q. Mason Color and Chemical Co.
Massillon Stone and Fire Brick Co.
Maxf Grinding Wheel Corporation.
Midland Terra Cotta Co.
Monongah Glass Co.
Mosaic Tile Co.
D. E. McNicol Pottery Co.
T. A. McNicol Pottery Co.

Nat'l. Fire Proofing Co.
Norton Co.

Ohio Pottery Co.
Onondaga Pottery Co.
Owen China Co.

Pennsylvania Salt Mfg. Co.
Perth Amboy Tile Co.
Pfaudler Co.
Philadelphia Drying Machinery Co.
Philadelphia Quartz Co.
Phoenix Glass Co.
Pittsburgh High Voltage Insulator Co.
Pittsburgh Plate Glass Co.
Potters Supply Co.

Reliance Firebrick and Pottery Co., Ltd.
Roessler & Hasslacher Chemical Co.

John H. Sant & Sons Co.
Saxon China Co.
Sebring Pottery Co.
Smith-Phillips China Co.
Standard Pottery Co.
Standard Sanitary Manufacturing Co.
Star Porcelain Co.
Steubenville Pottery Co.
Streator Clay Mfg. Co.
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Taylor, Smith & Taylor Co.
N. Thomas & Sons Co.
Trenton Flint & Spar Co.

United States Glass Co.
United States Smelting Furnace Co.

Veritas Firing System.
Vitro Manufacturing Co.
Vodrey Pottery Co.

Warwick China Co.
West End Pottery Co.
Western Stoneware Co.

Committee on Membership

F. H. Riddle, *Chairman*
Jeffrey-Dewitt Co.
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JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 4 April, 1921 No. 4

EDITORIAL

THE COLUMBUS MEETING

All members who attended the twenty-third annual meeting of the Society on February 21–24, were impressed with the wonderful growth of the organization and its rapid expansion into new fields of endeavor. With a record-breaking attendance of over four hundred members, seven professional divisions met for the reading and discussion of technical papers. The local committee under the chairmanship of Professor Arthur S. Watts, ably seconded by Mrs. Watts, had made every provision for the comfort and entertainment of the visiting members and their guests. The meeting was a memorable one, also, because of the return of Col. Edward Orton to the fold. A full account of the meeting together with President Minton's address and the proceedings of the Society and of the Divisions will appear in the Year Book.

DOES THE SOCIETY NEED A GENERAL SECRETARY?

The objects of the American Ceramic Society are to "develop the ceramic arts and the sciences related to the silicate industries by means of meetings for the reading and discussion of papers, publication of scientific literature, and other activities." The objects of the Divisions or professional groups must be the same as those of the society. The order in which the "objects" are listed in the "Rules" of the society is somewhat historical. When there were only a few interested in ceramic technology; when the literature was scant and there was no Federal Bureau and only

two Universities doing ceramic work, the principal objects of the society were: (1) meeting together; and (2) publication. The last object, "other activities," possibly was added to care for future developments.

With changing requirements caused by largely increased numbers of technically trained ceramic workers, by more literature, and by the activities of Federal Bureaus and Universities, the American Ceramic Society is now compelled to take up "other activities" as a prime object.

There is obvious significance in, and a natural consequence to, the forming of separate associations by the several industrial groups. Manufacturers have learned the futility of organizations having only general objects. They realize the advantages of coöperation, for definite purposes, with those in the same line of manufacturing. One of the natural consequences of this joining together of manufacturers in coöperative enterprises is the financing, in a large way, of technical investigations. The American Ceramic Society is the only organization whose single object is the promotion and publication of research in the science and technology of ceramics, and to this single purpose the Society has kept and must keep steadfast, and in this manner and for this purpose invite the respect of the manufacturers' associations.

In the early years when the members were few and ceramic technology almost in its beginning, there was no demand for specialization, but as membership in our society grew in numbers and the science developed, it was found necessary to create professional Divisions to the end that each group might have the opportunity for more thorough and intensive consideration of problems of particular interest to itself. This, however, has not fully met the requirements. If the American Ceramic Society is to meet its full obligations, it must consider as the most important of its "other activities," that of stimulating and providing direction for coöperative research through the agency of the professional Divisions.

Experience has shown that a Division can not be created or successfully maintained unless one of the main objects of the Division is coöperative research. Thus Divisions for whitewares, refractories, heavy clay products and abrasives have in the past

been either non-existent or unprogressive because no organizing effort has been made to stimulate and direct research in these particular fields. On the other hand, the terra cotta, glass, and enameling Divisions have prospered to the extent of their attention to coöperative investigations. The new Art Division has promise of success for it is being builded on a program in which meeting together and publication are only incidental.

The American Ceramic Society must make provision to meet the requirements of the manufacturers' associations or fail utterly in maintaining one of its avowed objects. Most of the manufacturers' associations have indicated their willingness and desire to finance technical investigations under the auspices of a Division provided the Society is prepared to furnish the necessary expert direction. The advantages to be obtained by manufacturers' associations placing the prosecution of their technical investigations with the Divisions of the American Ceramic Society are evident. Although the ceramic industries differ widely in many respects, each having much that is peculiar to itself, there is so much more that is common to all, especially in things technical, that the "ceramic arts and sciences" will advance more surely and more speedily, if all are kept united in one society.

Our society can, however, no longer continue to progress, solely by meeting together in conventions and by publishing technical literature. To do just that and that alone was a big undertaking twenty years ago but the very progress in ceramic technology resulting from these early meetings and publications has brought about widely different conditions today. The requirements of today must be cared for today and there is none more pressing than coöperative research in specialized divisions of "ceramic arts and sciences." The life of the Divisions will be the life of the Society and the failures of the Divisions will be the failures of the Society; and experience has demonstrated that the life and success of the Divisions is dependent upon the extent to which their numbers unite on coöperative research.

The organizing of new divisions, the maintenance of the necessary degree of coöperation among the various divisions, and the establishment and maintenance of relations with other organizations, together make up a field of labor requiring the full time and

energy of a General Secretary. The duties of such an officer would be quite apart from and in addition to those of a Recording Secretary and would be more in the nature of those which would be expected from a president whose tenure of office was permanent and who devoted all of his time to the work. Such an official would necessarily work in close coöperation with the President of the Society and would insure continuity of effort through changing administrations. It is important that the society give immediate attention to the matter of employing a full time General Secretary.

ROSS C. PURDY

ANNUAL TABLES OF CONSTANTS AND NUMERICAL DATA

By virtue of its membership in the Division of Chemistry and Chemical Technology of the National Research Council the American Ceramic Society is also a member of the International Union of Pure and Applied Chemistry and is privileged to nominate a delegate to each annual meeting of the Union. One of the international projects for which the Union is responsible, is the collection and codification of all scientific data, expressed in numerical form, which have been published in the literature of the world in every calendar year. The data cover chemical, physical, ceramic and technological constants of all kinds and the annual volumes published by the commission are indispensible to every worker and to every organization using data of this character since they eliminate the enormous labor of searching the world's literature in order to find the latest figures for a given property of some material.

The publication of the annual Tables was interrupted by the war but the organization was held together by its efficient secretary, Dr. Ch. Marie, of Paris, and after some reconstruction is now functioning once more. On page one of this issue we publish an announcement regarding the new volume, now in press, which will contain all data published during the years 1913–1916, inclusive. This is the first volume to appear since the beginning of the war.

ORIGINAL PAPERS AND DISCUSSIONS

THE MUTUAL RELATIONS BETWEEN ART AND TECHNOLOGY[1]

By Leon V. Solon

Abstract

An analysis of the purpose of decoration and of the characteristics of bodies, colors and glazes which determine their acceptability for the purposes of the professional decorative artist. The author urges the establishment of an Annual Exhibition where American ceramic artists may exhibit their products along side those of the sculptors, mural painters and other artists.

With the recent institution of a decorative art section in this Society, which is to occupy itself with matters appertaining to artistic progress, a new responsibility must be borne by each, be he a chemist, technician or artist, if this country is to add a worthy chapter to the brilliant history of our craft. This recognition of artistic activity as a subject of general interest for our membership, has been tardy, possibly, for the reason that achievement in that direction has not compelled interest of recent years. Be that as it may; where results of the highest order depend upon a perfect adjustment of contributory effort (as they do in ceramics), the two main contributory activities, the technical and the artistic, can not advantageously develop apart; it is therefore essential, to define in a general way, the mutual relation of arts and technology, and to locate vital points of contact. I have attempted to discover where energy is lost through lack of comprehension of what the decorative sense seeks in certain technical achievements; and to draw attention to certain professional view-

[1] Received March 5, 1921.

points of the decorative artist which determine the acceptability of bodies, colors and textures.

Beauty in any art, whether a fine or a decorative art, is realized in a measure through the development of the characteristic. In our art, the characteristic finds its clearer expression in plasticity, texture, and color quality, all of which are now only available as media of effect in such form as the technician produces them. The artist conceives an effect and is stimulated to a higher degree of attainment, or restricted in execution, proportionately to the adequacy or inadequacy of the technician's efforts. A technician who contrives any accessory without acquainting himself with the function it is to perform, is adopting the unscientific procedure of taking shots at a venture; yet unlimited instances can be cited in our industry where bodies and glazes are produced under precisely such circumstances. For that reason, if scientific effort is to realize its maximum decorative utility, the technician must direct his energy, and plan procedure, with a clear comprehension of those artistic standards by which his labor will be judged fruitful, or discarded as useless.

Ceramics, in common with all industrial arts, consists of two distinct but interrelated activities; the first of these, if we accord procedence in the order of evolution, concerns itself with the lower purpose, the utilitarian; the second, while recognizing the original incentive, is directed to investing the useful with beauty, as a major objective far surpassing the creation of convenient devises for mundane requirements.

Modern civilization has evolved obvious economic problems as a result of complex circumstances; for many years the energy and ingenuity of the technician have been almost exclusively concentrated on their solution. Far-reaching research and perfection of method in production have achieved the remarkable result that, in many branches of the industry, technical excellence exists as a matter of course, which none can afford to claim as a distinction; for the reason that it exists in the achievement of many. At this stage of progress, pre-eminence must be sought along a different path. The mechanical standard of faultless uniformity must be relegated to a place of secondary importance in an essentially commercial class ruled by competitive price;

in the first rank superiority will exist in aesthetic quality, evidenced in treatment. By treatment I do not mean the development of decorative expression alone, but include in that term the manipulation of such factors as texture and color in body and glaze, with the direct intent of stimulating intellectual processes, and creating forms of sense-appeal that are aesthetic by nature.

With this higher and more spiritual objective, all that which bears upon standardization or industrial economics, must naturally gravitate to the sphere of routine; the fortunate few who are endowed with the rare gift of aesthetic discernment, will enter a field where their achievement will be recorded in history and their handicraft be preserved as milestones on the road of progress.

Some may inquire as to the way in which the uninitiated may seek this new objective. The chemist, for instance, who is proficient in the creation of colors for decorative purposes, may have doubts as to whether his untutored chromatic sense is adequate to guide him to the limit of his capacity. Unfortunately, at the present time, decorative proficiency in the ceramic industry, of this and other countries, is far behind technical achievement; with the result, that there is no great progressive artistic movement which might be observed with the purpose of regulating scientific research in a clearly indicated direction, so that obvious decorative requirements might be anticipated by the technician. The indication is, that decorative ceramic development will, in the near future, be subordinate to the leadership in stylistic treatment of other more progressive crafts. By this I mean, that the decorative artist or architect who carries out the interior finish of a house, will encourage the purchase of such ornamental or dinner ware, or tile, as conforms to the prevailing vogue in treatment; and that the ceramic designer who disregards such preferences, sidetracks his product. The same condition exists in faience and terra-cotta; those designers in factories who are out of touch with the rapid exchange of preferences which are succeeding each other in architecture in our day, hold their product back to those markets where the minimum price has the maximum chance. What is the actual condition of our industry today, in those types of products where artistic quality in technique and treatment means more than cheapness? How does it appear from the

vital angle, the angle from which it is viewed by men whose approval can give it rank among the progressive industrial arts? Let us assume a hypothetical case: A man of prominence and distinguished attainment in the decorative arts is attracted to our craft by the desire to create effects as beautiful as those that fascinate him in historic ceramics. His first step will be to pass in review all that is available for decorative effect in current production, in pigment and texture. His initial impression will undoubtedly be, that the aspirations and ideals of those who create the media of effect, differ radically from those of the men who use those media, to produce the ultimate effect. The artist in selecting a group of pigments to create that entity of effect which is known as a "color harmony," seeks certain chromatic factors in the colors selected, which are the connecting links between color units. Those chromatic factors in colors, which I will describe as "common tone factors," exist between varying and different tints; these are of secondary importance if judged by their radiant energy, but are of vital importance in the establishment of mutual relations between color units assembled in groups for artistic effect. This factor which the decorative artist urgently needs to facilitate chromatic adjustment, and to add subtlety to character, is ignored by our color-makers and is encountered with just sufficient accidental frequency to prove that absence is due to non-perception, rather than to technical obstacles.

A further examination will reveal the fact, that the ceramic chemist's work in color is a series of separate and unrelated units, made without regard to characteristic color qualities capable of group formation, though he is quite conscious that the isolated color in decoration is not the prevailing method of use. The idea of creating palettes with a prevailing tonal relation does not appear to influence the majority of color-makers. The individual preference of most color-makers is to make colors of the intensest purity, carefully eliminating those underlying tones which the decorative colorist seeks first. That underlying tone in a composite color, is comparatively inactive, until placed alongside another composite possessing a tone element that corresponds to it; the affinity in those underlying tones constituting a relationship between the composite tones of a harmonious nature. There

are certain glazes I have in mind, which alone would be described as nondescript and lacking in individuality; but which, when included in a group of colors having a tonal relation to them, assume a quality of the greatest subtlety and beauty. Such tones would in all probability be rejected by the majority of technicians as failures, through lack of appreciation of their function in harmony and their decorative value. The prevailing inclination of the chemist for the maximum degree of radiant energy and tint purity, meets only the exceptional need of the decorative colorist. Such colors in the majority of cases could serve only as accents in an adjusted color group; the result of a group of units each with a distinct power for emphasis, is as unacceptable as over-emphasized music, action or speech. I would recommend that color-makers practice a new species of observation, which would be cultivated by placing colors alongside in pairs, in order that eye and brain be activated to detect the mutual affinity, repulsion and reaction of each upon the other. By the development of a sense of this description, results will be achieved by those whose temperament permits such notation, which will economize effort and contribute to artistic progress.

There is another extremely important point of observation to be developed in glaze making, which is one from which the decorative colorist judges the artistic value of a glaze: I refer to quality of texture. Texture is estimated by the artist from an entirely different standpoint from that of the technician; the former judges visually, the latter by touch. Texture in the artist's brain is indicated by the degree to which surface absorbs light rays, or reflects them. Variation in qualities of decorative effect demand a range of textures to be met by various surfaces, with the maximum degree of reflection and absorption as the two extremes. In the light-absorbing type, the area of intensest illumination is greater, lower in tone, and less scintillant than in the reverse class, a distinctive tone quality characterizes each type. If a constant study were pursued by technicians, to note the reaction of color to light, in accordance to its capacity for absorption or reflection, the great importance of this point of view in guiding color production can not fail to impress itself upon every observer.

I believe that at the present time technical achievement in

ceramics equals the total of experience in all ages; how is it that this vast fund of information is unrewarded with due credit, and its existence unsuspected by the art world or general public? Why is it that beautiful laboratory specimens of colors, which equal and often surpass their historic prototypes, should not enjoy a corresponding aesthetic prestige? The reason is simple and obvious. Individually, each is a unit of decorative effect, in the same manner that a musical sound is a unit of musical effect, and a numeral a mathematical unit. Such units possess interest only through the mental process of association, when placed in combination with other units of their kind; in the case of chromatic tone, or musical tone, the beauty of the unit is relative to the character of sense appeal, or imagination, that is stimulated through the manner in which it is associated in effect. For this reason the laboratory achievement, without decorative interest, can only possess a technical interest, and be enjoyed solely from a scientific standpoint; such limitation in appreciation excludes that class of individual for which the effort was originally undertaken. Can it therefore be maintained that the aesthetic objective in technical endeavor is a matter secondary or of negligible importance to the technician?

This consideration leads us to another serious question: How is adequate decorative quality to be developed? It is my conviction, resulting from an abundance of signs, and unmistakable evidence, that the United States will, during the coming century, lead all other nations in the decorative arts. In decorative metalworking already, particularly in wrought iron and bronze casting, the highest achievements of Europe are out-distanced. The most intricate weaves of Italy, Spain and France possess no difficulties that the American weaver can not master and reproduce; they are now seeking their individual form of art expression, which they will undoubtedly find. Furniture also is making astounding progress in technique and treatment. In every instance, progress is the result of the clearsightedness of manufacturers, whose ambition to excel in their crafts caused the commercial standards of mechanical excellence to rank in their estimation as little better than mediocrities. In what manner can we revitalize our craft, that it may achieve beauty in the eyes of those whose high stand-

ards makes their approval a hall-mark of merit? The old method, which staked all on manual training, will not suffice today, and the demand for superior achievement is too urgent to put off meeting it until the next generation matures. The demand of the American public, the most discriminating of our time, can not be met by a mechanical training of young men and women to laboriously reproduce Sevres or Crown Derby; factory-hacks can not bring our industry on a par with others in which every effort is strained to attract versatile talent capable of developing vital energy from historic tradition. If we rely solely on factory tuition or technical schools conducted on similar lines, we will fail to emerge from mediocrity, for the reason that the spontaneous decorative expression which characterizes all historic styles, is only recognized there in the idiosyncracies found in the confirmation of decorative detail. The means for worthy artistic achievement are to our hand today if we care to avail ourselves. Let those members of this society who see the need for new life in American ceramics, group themselves together annually under the auspices of some such progressive society as the Architectural League of New York. At the annual League exhibition, where the best of other crafts is gathered together, let the Ceramic Society show the American sculptor, the mural painter and the American art world generally, that our technicians have produced media for beauty which can equal that of any historic period. I have had very many conversations with men foremost in the ranks of the various branches of high and of applied art in this country who long for the beauties of ceramic color in their works; such men are ready to respond to your call, and to create beauty with what are now but formulae. The expense involved in retaining or employing prominent American artists, convinced as they are of the possibilities, is trifling when set beside the prestige that would accrue from success—and as business men we need not be reminded of the cash value of prestige. Next year members of the society should be represented at the League Exhibition in association with distinguished American artists, and the naissance of American Ceramic Art should be recorded in the future histories of our craft.

The public has clearly shown its impatience with commercial

standards and its boredom with mere technical excellence; it wants *treatment*, and for a time has lavished enthusiasm in protest on the mishandling of clay by the peasant potter. When a premium is placed upon lack of technique by a highly educated class, as in this case, we must record deduction from an unmistakable sign, and alter our course. The present and future credit of American Ceramics depends upon an infusion of new blood; let the art world supply the red corpuscles.

16 E. 41 St.
New York

AN ELECTRIC VITREOUS ENAMELING OVEN[1]

C. W. Mehling and Jas. W. Carpenter

ABSTRACT

Comparison with older types of furnaces.—In marked contrast with the oil, coal and gas furnaces the electric furnace eliminates damaged ware and makes possible the utilization of the entire heating space. Its initial cost and the fuel costs are double those of the older types but it admits 25 per cent increase in weight per charge and 30 per cent in charges per hour.

Description and operation.—Details of construction are given. The electrical equipment is explained together with the methods of temperature record and control. Details of operation are given.

Cost of operation.—With an initial cost of $8000, the cost of the electrical power has been $2.00 per hour for a 10-hr. day which would be reduced to $1.56 per hr. for a 24-hr. day.

Production results.—With a production of 900 lbs. of ware per hr. the enamel finish is more satisfactory than with the older types of furnaces.

Future improvements.—Preheating chambers and double end operation are suggested.

One of the most momentous improvements of recent years in the art of vitreous enameling has been the application of the electric furnace to the heating process. The use of electric current for heating in the steel and in non-ferrous furnaces, in japanning, core baking, oil tempering and similar industrial operations has now been extended to the enameling process.

Brief reference may be made to the disadvantages and troubles which have been encountered in the operation of the older methods of obtaining the temperatures (1500° to 1800°F.) required for satisfactory enameling work. With regard to the coal furnace it may be pointed out that in order to maintain the temperature of 1700°F. it is necessary to employ an expert fireman and there are even then times when atmospheric conditions make it impossible, even with the very best of firing, to procure and maintain this constant temperature. The most serious defect in the coal furnace is the muffle which periodically sags and breaks, thereby

[1] Received Feb. 23, 1921.

causing damage to or loss of ware by allowing the rack rests to go down and regularly at intervals of from two to twelve months it is necessary to renew the muffle and overhaul the fire-box and furnace. This usually means a shut down and loss of production for from two to four weeks. Moreover, in the coal furnace the sulfur fumes which are injurious to the ware and frequently cause a high percentage of seconds or of job lots are so difficult to eliminate that a certain factor in production must ordinarily be allowed for the damaged output which will be obtained from the ordinary furnace.

The oil furnace and the gas furnace have the same draw backs as the coal furnace. They will not hold the heat in burning large ware and the bottom of the muffle burns out even faster than it does in the coal furnace. Likewise, the great variation in temperature between the front and rear ends of the oven usually reduces the actual space which may be productively used in burning. Such ovens are handicapped by the time required to bring them from a cold condition to operating temperature, and part time operation is practically impossible. Also the fuel supply for coal and oil furnaces is dependent upon railroad and labor factors which are not entirely dependable. The space occupied by the older ovens is greatly increased by the fuel storage room needed.

In sharp distinction from the preceding faults of the older type furnaces it may be indicated that in the electric furnace there is no trouble with the muffle and the consequent loss of ware by falling rack rests since the electric furnace has no muffle and the rack rest is built right up from the foundation. Furthermore, the even distribution of heat is a feature which can be obtained only by the electric installation and the furnace can be loaded from the rear wall right up to within six inches of the door and burned down to a finish, the operation giving a clean white enamel without spot or mar. Atmospheric conditions of course have no influence upon the electric furnace as it needs no draft.

The initial cost of the electric furnace is of course considerably higher than any of the other types, but the difference in maintenance cost, the saving in space, and the cleanliness soon make the difference in price a matter of secondary importance. The fuel cost on an hourly basis for the electric oven is likewise higher,

running nearly double that of coal, gas, and fuel oil for twenty-four hour day operation. However, the additional output of the electric furnace as determined by relative tests shows that the actual cost per pound of metal handled will compare very favorably with any other form of fuel. When the electric furnace is able to handle in ten hours at least 170 heats of No. 22 gauge steel against 130 heats of the same material by the coal furnace, and with 25 per cent greater weight per charge, the comparison in actual cost of fuel assumes a different aspect and is actually in favor of the electric installation.

The oven in which we are interested is the first commercial installation of such an equipment in the United States, and has been installed within the past six months in the factory of the St. Louis Brass Mfg. Company at 2615 Washington Ave., St. Louis. The installation was made under the direct supervision of Mr. E. F. Guth, President of the St. Louis Brass Mfg. Company, and the record established thus far has fully justified him in the adoption of this method of furnace heating.

The furnace measures approximately 12 feet 11 inches in depth by 7 feet 8 inches in width and 7 feet 4 inches in height in overall dimensions. The actual enameling space is 4 feet wide by 2 feet high by 10 feet deep. The heat is obtained from nichrome ribbon woven up and down on each side of the furnace over special hanger brick in a lattice like arrangement. The winding on the lower sides is double while that on the upper sides is single except for about 22 inches back of the door where a double winding is installed to make proper allowance for the escape of heat when the door is opened and closed for loading and unloading. The nichrome ribbon is approximately 5/8 inch wide and 0.05 inch thick. There are six heating elements in the furnace and micrometer tests made after sixty days operation showed no physical change in the windings. Similar nichrome elements for heat treating, etc., have been in use for over three years without apparent change.

The furnace brick work is built up in the following fashion: There is first a four inch course of common fire-brick and the special hanger brick for the support of the heating elements are incorporated as a single row in this course. Outside the fire-brick there

is a 9 inch course of insulating brick and then a 4 inch course of common red brick. It is proposed to cover the entire furnace with a coat of asbestos from two to four inches thick. The door is about $4^1/_2$ feet wide by 3 feet high and is made of insulation brick and steel frame. As far as possible special monel metal racks are used in carrying the heating work to reduce the area and weight of supporting metal and prolong the life of the racks.

The electrical equipment for the furnace consists of the ribbon windings which have a minimum rating of 150 Kilowatts or roughly 200 H. P., and are operated on 230 volt, 3 phase, 60 cycle current and protected by special fuses. An automatic electric control panel containing contractors and automatic switches provides automatic record and control of the temperature of furnace. The record chart shows the temperatures of both the ribbon and the air and the furnace can be operated continuously at any temperature up to 1800°F. The nichrome windings in the furnace are connected to the control apparatus and to the transformer substation by heavy copper wire installed in conduit and the entire oven installation is on a separate oil switch which gives it individual control independent of the lighting and power load of the factory.

Guarantees of performance of the furnace were given at the time of installation as follows:

1. The oven will bake eight pounds of material per kilowatt hour including racks which are figured on the basis of one-half of above weight, when oven is operating at full capacity of 1200 pounds of material per hour including racks.

2. The electric heaters will maintain continuously a temperature of 1700°F. under an operating cycle of 3 minutes and 40 seconds, door open 10 seconds to load and open 10 seconds to unload with average bake of 3 minutes and 20 seconds.

3. The maximum demand of the heating unit will not exceed 150 kilowatts..

The cost of the furnace approximates $8,000.00 consisting of about $4,000.00 for the nichrome windings, hanger brick and electrical control equipment, $800.00 for electric wiring and material, $1500.00 for oven construction, and $1900.00 for transformer capacity and substation expense. For certain installations

this expense would of course be increased, if the electric furnace were the only electrical equipment installed, as in that case the total substation cost would be placed entirely upon the furnace. For two or more ovens the substation cost would be divided and the net first cost per oven would be reduced. At the present time the St. Louis Brass Mfg. Company furnace is being operated only on a night shift and the cost has approximated $2.00 an hour with an average hourly consumption of 125 kilowatts. For a 24 hour day operation and the consequent reduction in overhead expense, the cost for current would be about $1^1/_4$ c. per kilowatt hour, giving an hourly cost for the furnace of $1.56.

The results thus far obtained have been highly satisfactory, particularly with regard to the quality of the output and the speed with which the oven can be brought to temperature, 1700°F. being reached in 12 hours. To reach this temperature with a coal furnace would require up to 48 hours, with oil or gas furnace, about 24 hours. The electric furnace has been cut out at 5 A.M. with temperature at 1700° and cut in again at 6 P.M. at 1200° and in forty minutes it has been ready for work at 1600°. The production per hour is 2338 pounds of ware and racks, with 130 kilowatts per hour, the number of charges being 24. This means 900 pounds of enamel ware at a cost of $2.00 for the electric energy.

The outstanding features of the oven have been the extreme speed at which it can be operated, the cleanliness and improved appearance of the enameling room, and the absence of rejected pieces through improper burning or damage from fumes or soot. The most pleasing feature of the oven has been the finish on the ware as it has been far superior to the bake obtained in any other way.

Future installations of this nature can probably take advantage of facts learned in the use of the present furnace and it is probable that other ovens to be constructed will include a preheating chamber where the temperature will be kept at from 800 to 900°F. and there are possibilities of a double end furnace so that work can be fed in at one end and removed at the other, thereby greatly increasing the speed and amount of metal baked.

In the installation as thus far operated the results predicted for electric heat in this work have been fully demonstrated and the

many advantages of electric heat for enameling as well as for the many other purposes to which it is being adapted have been fully justified, and it seems quite apparent that there is a wide field for the application of electric heat in the enameling industry.

St. Louis Brass Co.
and
Union Electric Light & Power Co.
St. Louis, Mo.

THE LAYOUT OF A BRICK OR TILE PLANT WITH A CAR TUNNEL KILN.[1]

By T. W. Garve

Description of a hollow tile and drain tile plant using a tunnel kiln. The routing of the material (shale) and product is described under the following heads: dump cars, plate feeder and crusher, storage, dry pans, screens, storage, pug mill and tile machine, combination waste heat and radiated heat drier, kiln car loading station, tunnel kiln, kiln car unloading station, stock shed. A detailed diagram is given.

It is but very recently that car tunnel kilns have been seriously considered in this country for burning common clay wares such as brick and tile.

It would seem at a first glance that the long stretch of a tunnel would not fit well into a satisfactory layout of a brick plant. As a matter of fact, however, quite a satisfactory arrangement can be worked out with a tunnel kiln for a plant of average capacity. For larger plants with several kilns it is necessary to give a good deal of study to the track arrangement in order to avoid congestion in certain places. The burning of the common clay wares in a tunnel kiln is one problem and the handling of the ware is another equally important problem.

In plants producing high priced products such as sanitary ware, table ware, and pottery, it is to a great extent the quality of the ware that pays the interest on the investment and yields the profit, while on a common ware plant the output will usually be the important factor. The car burden in a pottery represents a value which would be expressed in three figures, while in a brick or tile plant the car may be worth ten to fifteen times as much as the ware.

In a plant manufacturing common ware with a car tunnel kiln it is important that labor be reduced to a minimum and hence

[1] Received February 15, 1921. Presented at the Columbus meeting of the Society, February, 1921.

automatic operation must be utilized as far as possible. The loaded as well as the empty cars, being heavy for this kind of ware and output, can not be conveyed by hand, and proper car moving devices must be installed.

The car tunnel kiln introduces a new and different system of brick making. Such a plant has to be operated continuously, and more skillful labor is required than was customary on the old type "brick yard." One of the advantages of the tunnel kiln, or continuous kiln is that it makes continuity of plant operation imperative and eliminates excuses for frequent shut-downs.

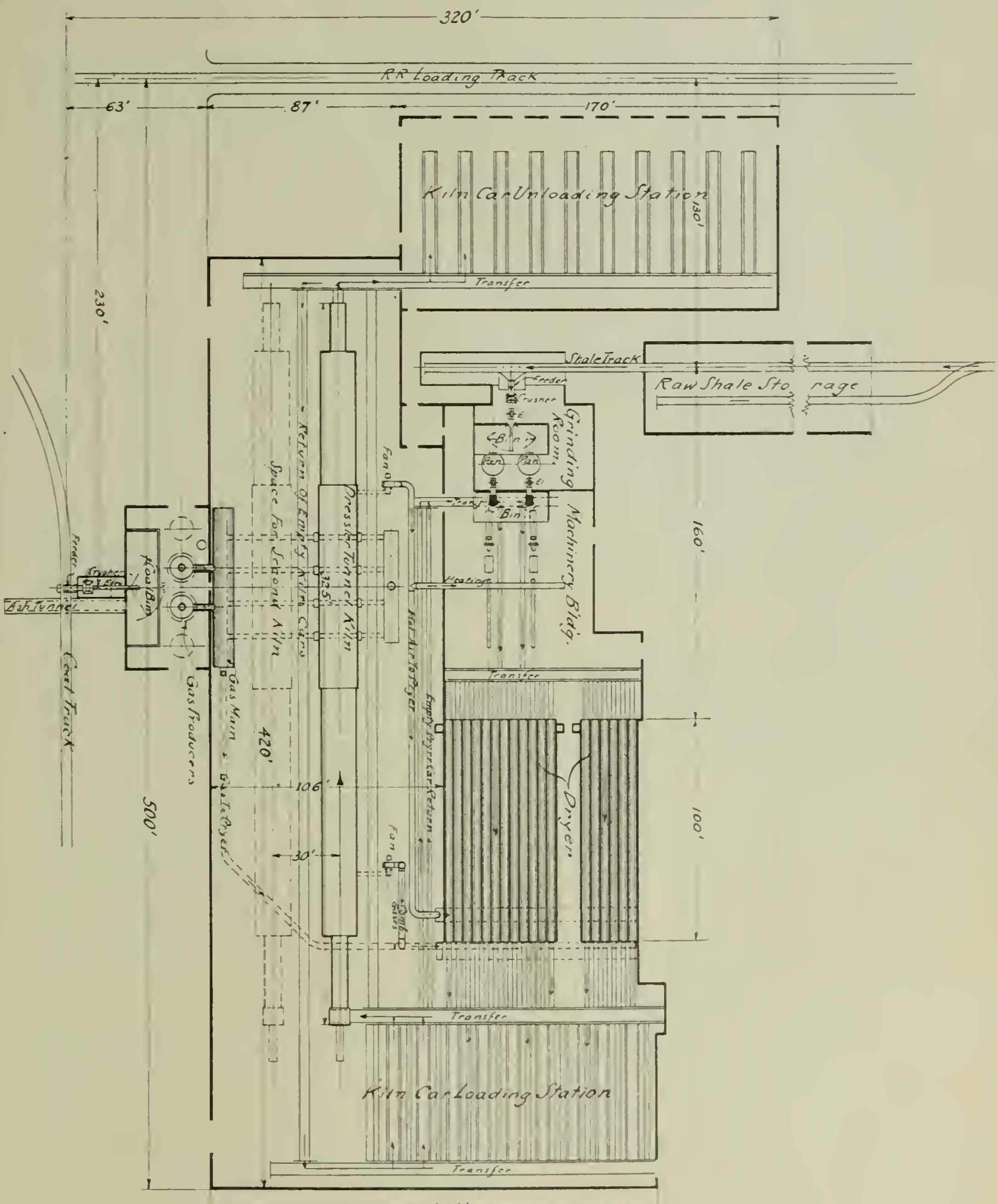
The Franklin Brick & Tile Company of this city is completing a plant for making hollow building tile and drain tile with a Dressler tunnel kiln, at Taylor Station, nine miles east of Columbus. The illustration gives the outlines of this plant with the exception of the raw clay storage building not yet constructed.

The shale is hauled up in side dump cars by a gasoline engine and dumped into a pocket above a plate feeder and crusher. One advantage of a plate feeder is its insurance against accidents, since a man, should he fall into the hopper, will have ample time to climb out unharmed.

The crushed shale is elevated, stored and fed to ten-foot dry pans with gravity hopper bottom. The ground shale is then elevated, screened, stored, and fed to the pug mill and tile machine.

The grinding room is dust proof and arranged so that one man is able to look after it, even for a capacity of 200 tons a day.

The drier is a combination of a waste heat and a radiated heat drier using the hot air from the cooling end of kiln, the combustion gases from the kiln, or producer gas from the gas main. If there is sufficient waste heat from the cooling ware, the drier may be operated as a waste heat progressive drier, but lacking sufficient hot air, the latter may be supplemented by waste gases introduced into the drier through the producer gas burners. It will be understood that the hot air is introduced among the pieces of ware as in a waste heat drier, but the combustion gases are confined to the radiated heat duct. In winter it is proposed to use the hot air from the cooling ware for factory heating, and in the event that the combustion gases alone do not give sufficient heat for



The layout of a brick or tile plant with a car-tunnel kiln.

drying, we can resort entirely to producer gas and the operation of the drier is simply that of a producer-gas fired radiated heat drier.

After passage through the drier, the cars are taken to the "kiln car loading station" which has depressed tracks for the kiln cars between the drier car tracks. From here each loaded kiln car is by transfer taken into the kiln. Each car will have to carry about two and one-third tons of ware, and to maintain the estimated capacity, a car must be introduced about every 33 minutes.

The cars are taken out at the other end of kiln and transferred to the "kiln car unloading station." The kiln car tracks here are also depressed to make the handling easier and quicker. An electric lifting truck operating on platforms between these tracks takes the ware directly into the railroad cars or stock shed.

Alongside the kiln a track is provided for returning the empty kiln cars from the unloading to the loading station. The empty drier cars are returned on tracks inside the kiln building along the drier.

The kiln is guaranteed to burn 100 tons of hollow ware per day, but space has been left for a second kiln and two more gas producers, and tracks and drier can be extended if necessary.

There are two railroad switches, branches of a Y, one being a loading track and the other a coaling track. The coaling station in front of the gas producers consists of a plate feeder below the track, a coal crusher in a pit, an inclined elevator with swivel spout and a large coal bin in front of the producers. The power throughout the plant is electric and, with a few exceptions, the drives are noiseless chains from individual motors.

The kiln car loading station was necessary in order to keep the kiln supplied during the night and over Sunday, and for the same reason the kiln car unloading station had to be provided to take temporary care of the cars taken from the kiln during the night and on Sundays. This requires 66 kiln cars exclusive of the 44 cars in the kiln. The number of extra cars can be reduced, if night shifts are employed in loading, unloading, and transferring.

It might be possible to eliminate the second handling, namely, the transferring of the green ware from the drier cars to the kiln

cars, thus eliminating the kiln car loading station. If the kiln cars could be loaded at the machine with their full capacity, and if they could be shifted, dried, and burned without damage to the ware, we could substitute a tunnel drier for the kiln car loading station from which the cars are taken at the intervals necessary for feeding them into the kiln.

NOTE ON THE EFFECT OF TIME ON THE DRYING SHRINKAGE OF CLAYS[1]

By R. F. Geller

ABSTRACT

The drying shrinkage of clays were studied to determine how quickly different types can be dried and to note whether or not the time of drying influences the amount of shrinkage. Three shales, two ball clays and one fire-clay were tested and the following conclusions reached: (*a*), drying time depends largely on water content; (*b*), the structure of the clay is an important factor; (*c*), the amount of total shrinkage is proportional to the water content; (*d*), the amount of total shrinkage is not influenced by the rapidity of drying.

The primary object of this work was to find how quickly different types of clays can be dried and incidentally to find whether or not the rate of drying influences the amount of shrinkage.

Three types of clays were studied: three shales, two ball clays, and one fire-clay. Each of these clays was pugged thoroughly to good working consistency, wedged by hand and made up into two inch cubes by pressing into brass molds. From each clay 48 specimens were made, six being used in each drying experiment. The average values from each set were used in computing the results.

Immediately after they were made, the specimens were weighed in air, placed in kerosene for 24 hours, and the weights again determined both in air and suspended in kerosene. The specimens were then placed in an electrically heated oven whose temperature was determined by means of a thermocouple connected to a recording potentiometer. The drying consisted in bringing the clay cubes from room temperature to 100°C. along a straight line time-temperature curve. The length of each drying period varied from 1 to 8 hours.

The samples when removed from the dryer were at once im-

[1] Received Feb. 14, 1921. Published by permission of the Director, Bureau of Standards.

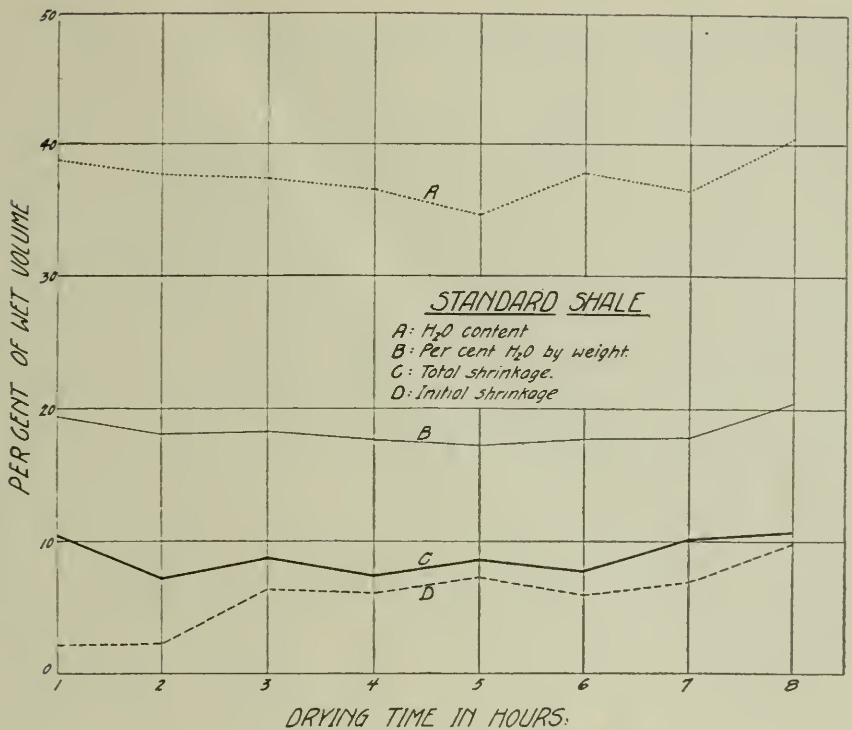

STANDARD SHALE
A: H_2O content
B: Per cent H_2O by weight.
C: Total shrinkage.
D: Initial shrinkage
PER CENT OF WET VOLUME
DRYING TIME IN HOURS.

FIG. 1.

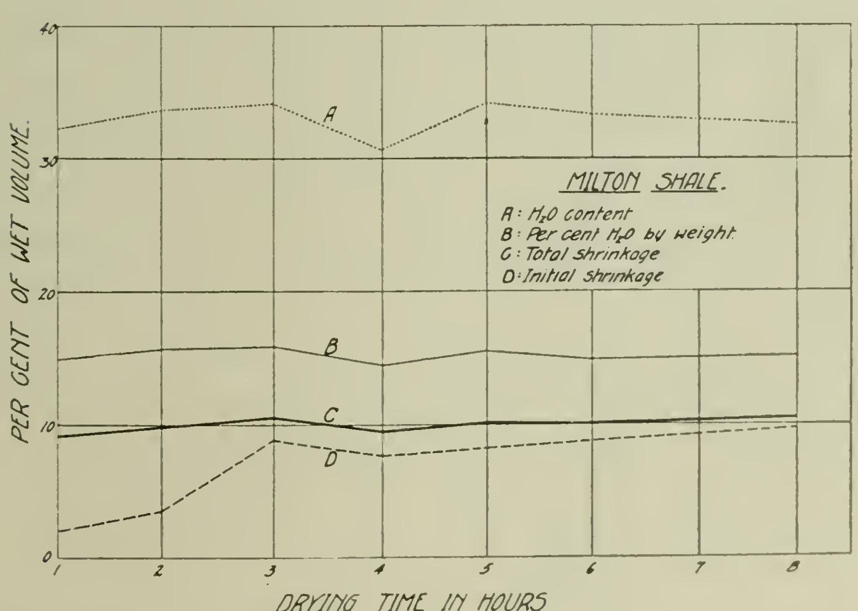

MILTON SHALE.
A: H_2O content
B: Per cent H_2O by weight.
C: Total shrinkage
D: Initial shrinkage
PER CENT OF WET VOLUME.
DRYING TIME IN HOURS

FIG. 2.

mersed in kerosene for 24 hours and their weights, in air and suspended in kerosene, again taken. From these values the volume shrinkages were computed. The total shrinkage of three samples from each set of six was likewise determined by heating them to constant weight at 110°C., the volumes being again computed from the weights in air and suspended in petroleum. All shrinkage measurements were based on the volume of the specimens in the plastic state. The results of this work are shown graphically in the diagrams of figures 1 to 6. Each diagram consists of four curves of which A represents the water content of the specimens in terms of the wet volume, B the weight of water in terms of the wet weight, C the total shrinkage in terms of the wet volume (obtained by heating the clay to 110°C.), and D the shrinkage determined at the end of the several periods. Figures 1, 2 and 3 represent three shales and we observe that in each case the partial shrinkage parallels the total shrinkage after four hours drying. In no case, however, do the two curves coincide, although in the the diagram of figure 3 they approach each other very closely.

The constant variation noted in the longer drying periods is due in part to the small shrinkage taking place between 100° and 110°C., it being borne in mind that the first drying was carried just to 100°C. and the complete drying to 110°C. There is a tendency for the curves C and D to coincide for longer periods, which is to be expected. One should expect that the minimum drying time allowable in practice for pieces corresponding to the size employed in this work would be represented by that point at which the two curves first coincide. Such a point is not reached in these curves, but they approach each other closely enough to warrant the statement that, theoretically speaking, shales could be dried in four hours, provided the heat treatment corresponded to the one used in this work, and likewise provided that the steam were removed promptly from the drying chamber to avoid possible reabsorption. Of the three shales, that from Ridgeway seems to show the fastest rate of drying. It is evident that shales as a class should show a more rapid capillary water movement than the more plastic materials.

Figures 4 and 5 give the curves obtained with two ball clays, the former representing an English and the latter an American

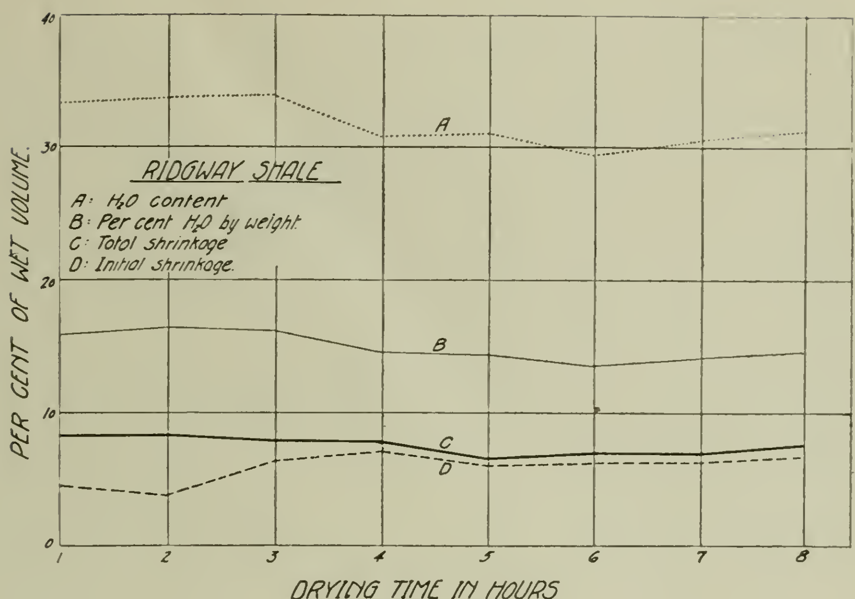

RIDGWAY SHALE
A: H_2O content
B: Per cent H_2O by weight.
C: Total shrinkage
D: Initial shrinkage.
A
B
C
D
0
10
20
30
40
1
2
3
4
5
6
7
8
PER CENT OF WET VOLUME.
DRYING TIME IN HOURS

FIG. 3.

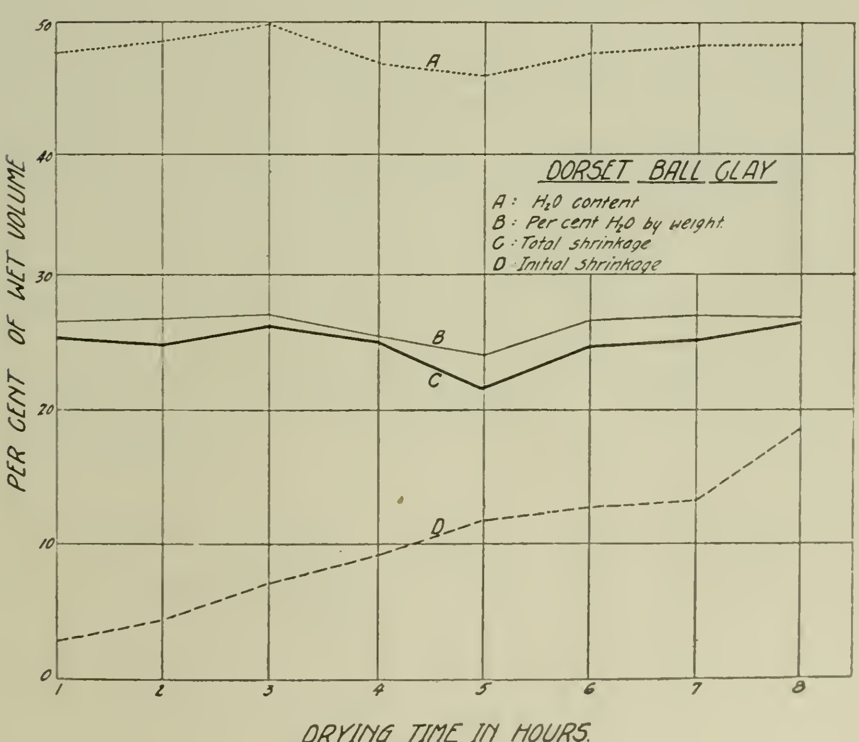

DORSET BALL CLAY
A: H_2O content
B: Per cent H_2O by weight.
C: Total shrinkage
D: Initial shrinkage
A
B
C
D
0
10
20
30
40
50
1
2
3
4
5
6
7
8
PER CENT OF WET VOLUME
DRYING TIME IN HOURS.

FIG. 4.

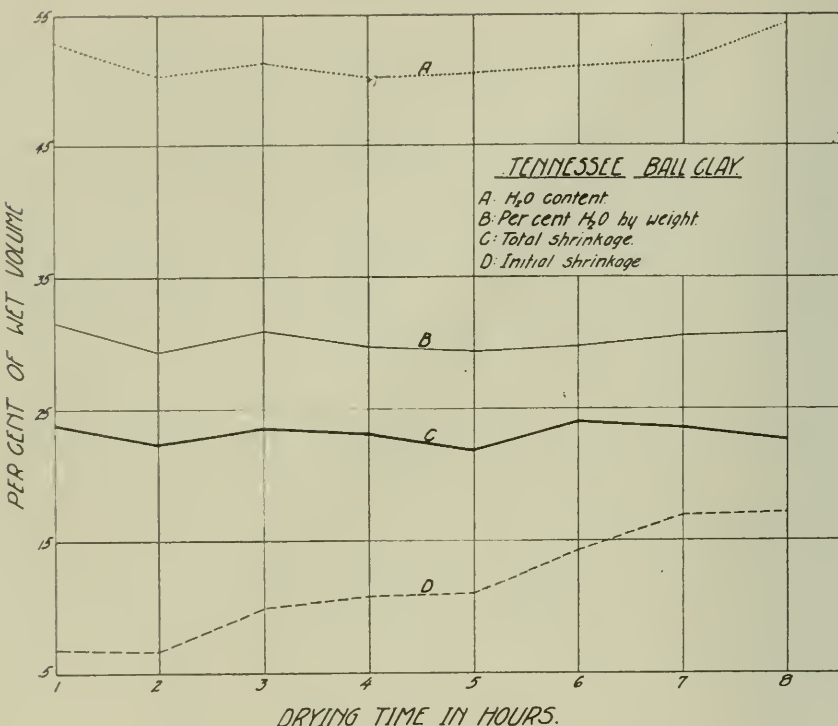

55
45
35
25
15
5
A
B
C
D
TENNESSEE BALL CLAY
A: H_2O content
B: Per cent H_2O by weight
C: Total shrinkage
D: Initial shrinkage
PER CENT OF WET VOLUME
1
2
3
4
5
6
7
8
DRYING TIME IN HOURS.

Fig. 5.

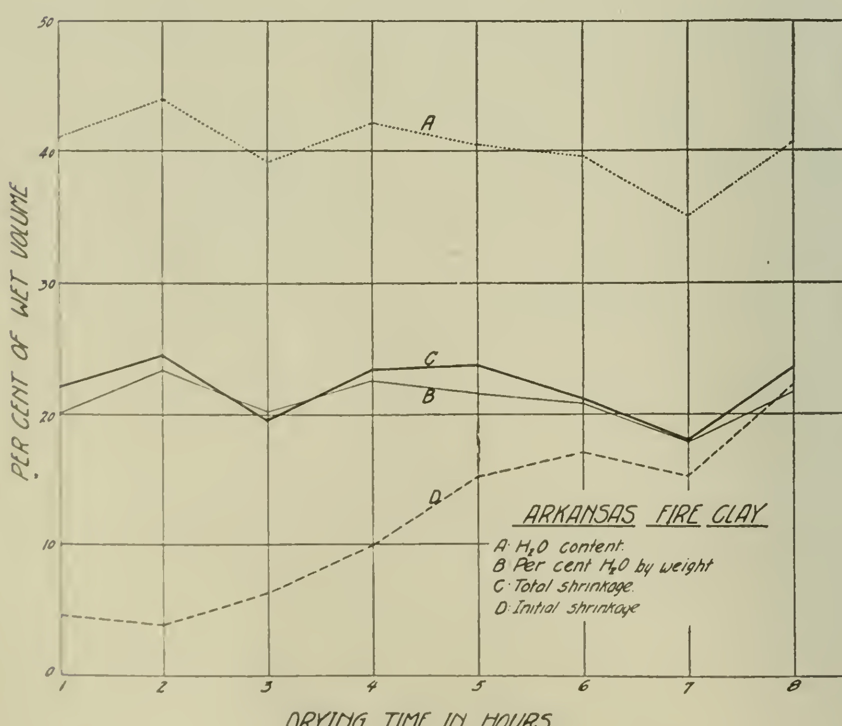

50
40
30
20
10
0
A
B
C
D
ARKANSAS FIRE CLAY
A: H_2O content
B: Per cent H_2O by weight
C: Total shrinkage
D: Initial shrinkage
PER CENT OF WET VOLUME
1
2
3
4
5
6
7
8
DRYING TIME IN HOURS.

Fig. 6.

clay. The water content of these clays is considerably higher and even after eight hours of drying a large amount of water remains in the clay. In fact, only 33 to 38 per cent of the water has been removed. The exceedingly fine grained nature of these clays renders it impossible to remove the water at anything like the rate possible in coarser grained materials. It is not surprising therefore to find that curves C and D are far from coinciding after eight hours drying. In the case of the Dorset ball clay, it is observed that there is a decided increase in the rate of drying between the seven and eight hour treatments, a fact which can not be explained from the data at hand. A comparison of diagrams 4 and 5 tends to indicate that the American clay dries more easily, in spite of the fact that its water content is greater. The diagram of figure 6 shows the drying behavior of a siliceous fire-clay. This material is very fine grained with a water content between that of the shales and the ball clays. This fire-clay approaches the total shrinkage quite closely after the eight hour treatment. From the data thus obtained, the following conclusions may be drawn:

First, the drying time required for a given material depends largely upon the water content; second, the structure of the clay, irrespective of the water content, is an important factor which must be taken into account; third, the total shrinkage is proportional to the water content; fourth, the total shrinkage is not influenced by the rapidity of drying, that is, more rapid drying does not tend to bring about a smaller shrinkage nor does longer drying tend to yield larger shrinkage values, at least not within the drying periods employed in this work.

Bureau of Standards
Washington, D. C.

A MERCURY VOLUMETER[1]

By Ernest F. Goodner

ABSTRACT

A new volumeter using mercury as the liquid for determining volumes of solids.

Existing volumeters.—The eight principal volumeters which have been in use during the past few years are discussed, the disadvantages and advantages being pointed out and the requisites of a satisfactory volumeter are outlined.

Description of new mercury volumeter.—The volumeter consists of a burette which may be raised or lowered by means of a rack and pinion. To the lower end of the burette there is a rubber tube attached which connects at the other end with a reservoir. This reservoir is at a fixed point, level with the bottom of the burette when raised to its highest point and is partially filled with mercury. The whole volumeter is, in action, a large "U"-tube with one movable limb (the burette). The volume is obtained by placing the briquette in the reservoir, causing a rise in the level of the mercury in both limbs of the "U"-tube. The burette is then lowered until the mercury has resumed its former level, this movement being the measure of the volume which is read directly from the graduations on the burette.

Mathematical analysis.—It is shown that a ratio of 1:1 of the reservoir and burette areas of free mercury surface will enable the reading of volumes as accurately as one can obtain the burette reading.

Comparative tests with other volumeters.—Tests of the action of mercury, water and kerosene show that they behave alike in obtaining volumes. No saturation of burned or dry briquettes is necessary when using mercury as the liquid. Volumes with pycnometer and overflow types of volumeters checked those obtained with mercury volumeter to within $^5/_{100}$ a cc.

Per cent variation of readings.—Results of three operators working independently indicate that for volumes above 25.00 cc. the volumeter is consistent within 0.2 per cent which is also the accuracy of the result.

Disadvantages.—1. The initial cost of about two pounds of mercury. 2. The slight tendency of the mercury to remain in cracks and holes of some briquettes, although readily shaken back into the reservoir. 3. A slight difficulty in obtaining the reading for the first dozen determinations.

Advantages.—1. No 12-hour soaking in kerosene is necessary for dry briquettes. 2. There is no draining of briquettes after immersion. 3. No

[1] Received Feb. 17, 1921. Published by permission of the Director, U. S. Bureau of Mines.

draining of liquid is necessary. 4. It is direct reading. 5. It is very speedy and accurate. 6. No adjustment is necessary before each volume is taken, and, when adjustment is required, it is very quickly accomplished. 7. There is no adjusting of ground glass stoppers.

Existing Volumeters

Throughout the country several types of volumeters, employing diverse principles, are in use for quick measurement of the volumes of ceramic products. A brief consideration of the disadvantages of each of these types will make clear the need for an improved volumeter.

Seger Volumeter.[1]—The Seger type of volumeter is the one recommended by the committee on standards of the American Ceramic Society for obtaining volumes of clay samples—plastic, dry, and fired. The only advantage which it possesses over the others is that it can handle a larger volume. The disadvantages have been summarized by Schurecht.[2] His criticisms are well-merited and apparent to anyone who has used this type of volumeter.

Pycnometer (Schurecht).—In order to overcome some of the objections, Schurecht used a true pycnometer method in which the weight of the briquette in air, the weight immersed in a liquid, and the weight of the liquid displaced, are used in determining its volume. This method involves two weighings for each volume, and a check-weighing of the pycnometer and liquid at frequent intervals.

In order to reduce the time of weighing, the balance is loaded so that the swing of the pointer represents exactly 0.1 gm. per scale division. This plan allows rapid determinations of the weights. For computing the volumes from the data thus obtained, a set of tables is used in which the values have been computed from laboratory data which depend upon the size of briquette and pycnometer used.

Shaw[3] has discussed and summed up the disadvantages of the pycnometer method in which weighing is necessary.

[1] Iowa Geological Survey, *Annual Report*, 14, 115 (1903).

[2] Schurecht, This Journal, 1, 556 (1918).

[3] Shaw, This Journal, 2, 487 (1919).

Direct Reading Pycnometer (Shaw).—Shaw illustrates a similar apparatus in the same paper which reads volumes directly by placing the briquette in a glass bottle and filling to a mark, removing the stopper and briquette, replacing the stopper and then refilling the bottle to the mark by means of a burette delivering through a tube in the stopper. The volume of liquid run from the burette into the bottle then represents the volume previously occupied by the briquette. The advantages listed by Shaw for his apparatus are: "(1) Speed; (2) simplicity; (3) low cost; (4) sufficient accuracy."

In the manipulation of the Shaw apparatus the briquette must be wiped so that there is no free liquid on the surface, and must be allowed to drain back into the bottle after removing until no free liquid remains on the surface, for two drops of water or three of kerosene are equal to 0.1 cc., and since the volume is to be determined to tenths of a cc., this amount could readily introduce an appreciable error. Obviously, this draining will take time. Any method in which the briquette is removed from a measured volume of liquid before the volume of the briquette is determined is bound to introduce this factor of draining. Again, the stopper must be replaced exactly as it was at first to insure the same internal volume, and lastly, the burette must be allowed to drain for at least three minutes in order to obtain an accurate reading.

Hubbard and Jackson Volumeter.—This volumeter is described by Hubbard and Jackson,[1] who give detailed results of tests upon different types of apparent-specific-gravity apparatus.

Goldbeck Volumeter.—In Hubbard and Jackson's article a description is also given of an apparatus in which the liquid displaced by the briquette is allowed to overflow into a beaker and is then weighed. This is, therefore, essentially an overflow type of volumeter in which weighings must be made, and the transfer of the liquid from one vessel to another is not an accurate method for fast work.

[1] *Proc. Am. Soc. Test. Mat.*, **16**, 378–401 (1916).

Staley Apparatus.—Staley[1] has developed a volumeter which causes the rise in level of a liquid due to immersing the briquette in a reservoir, to be magnified by having the rise take place in a tube inclined slightly from the horizontal and attached to the reservoir. The above method has the following faults. The least variation in the angle of inclination of the reading tube will vitiate the results; the volumeter must be calibrated, and considerable care exercised in its manipulation; the zero point must be adjusted every time a volume is taken. Although the apparatus is very accurate, if handled properly, it is rather fragile and hard to keep set accurately.

Spurrier Volumeter.—Spurrier[2] describes a sensitive volumeter in which volumes are read directly by means of magnifying the rise in the level of a liquid by forcing the displaced volume of liquid into a capillary tube. The operation consists of filling a reservoir to a given level, placing the sample in the reservoir, and then forcing the displaced liquid into a capillary tube by means of lung pressure applied through a rubber tube attached to the top of the reservoir. This does not require any draining of the sample after placing it in the volumeter and the volume is read directly on the capillary tube.

Spurrier uses this volumeter for small volumes only; a correction must be made for capillarity and the readings must be made under practically constant temperature conditions. Also, in returning the liquid to its original level, considerable care must be exercised in order that the exact level be reached. He states that no claims are made for speed or convenience, although the instrument is exceedingly accurate and very neatly designed.

Overflow Type of Volumeter[3] **(Schurecht).**—In this type the bar is placed in a cylinder or reservoir having an internal tube which discharges the liquid displaced by the briquette directly into a burette, where it is measured. This type has been in use

[1] U. S. Bur. Stands. Report on Construction and Tests of a Staley Volumeter, Verbal Request of The Committee on Standards of The American Ceramic Society, Feb. 5, 1919.

[2] Spurrier, This Journal, 3, 400 (1920).

[3] Schurecht, This Journal, 3, 730 (1910).

at the U. S. Bureau of Mines stations at Columbus, Ohio, and Seattle, Wash., for some time.

The disadvantages of this method are as follows: When water is used, a hard, thin coating of dirt often forms upon the inside of the burette, causing slow drainage and the clinging of drops of water to the upper part of the tube. Any vibration of the burette to cause better draining is inadvisable because this would result in a further flow from the cylinder. The waiting, as a result, slows up the operation. The same briquette does not give the same volume, if dropped or lowered rapidly into the cylinder as is obtained if it is lowered slowly, due to little ripples flowing over the top of the tube. In rapid work the volume reading of the same briquette, when placed in different sets, varies as much as three-tenths of a cubic centimeter. The liquid, particularly water, is liable to cling to any dirt lodged upon the overflow tube, causing an error, which is particularly liable to happen with crumbly briquettes. Undoubtedly, if sufficient care and time are taken, the results may be made to check closely enough for the ordinary volumes needed in ceramic control work. These disadvantages apply in a lesser degree to the use of kerosene for measuring plastic volumes.

The advantages of this volumeter are: (1) Simplicity of construction and operation: (2) no glass stoppers are used; (3) no draining back of liquid from briquette to the volumeter is necessary; (4) if twelve to twenty-four volumeters are used, a large number of volumes may be determined rapidly.

Requisites of a satisfactory Volumeter

The requisites of a satisfactory volumeter are, briefly, the following: (1) The briquette should not be removed from the container in order to obtain its volume; (2) the volume should be obtainable by direct reading; (3) filling the container to a definite level or recharging for each determination should be avoided; (4) saturation of the briquette before immersion should be avoided; (5) the results should be consistent and accurate to 0.1 cc.

If a volumeter can meet these requirements, it will be unusually fast and accurate.

A New Mercury Volumeter

While making preliminary tests of clay samples collected in the course of a survey of the ceramic resources of the State of Washington, the writer found that the existing types of volumeters required too much time to operate. Since eighteen volume determinations for each of three hundred samples of clays burned to different temperatures were required, a volumeter was designed with the object of increased speed of operation. Mercury was adopted as the liquid for obtaining the volumes, mainly for the reason that it does not "wet" the briquettes, whether they are in the plastic, dry, or fired state. The mercury does, however, fill the holes and cracks, thereby giving correct bulk volumes. The volumeter has been tried out very carefully in actual work as well as in comparative tests and has proved satisfactory.

Principle of Operation.—The principle of the new mercury volumeter is somewhat akin to that of the apparatus used by Spurrier, although differing in the method of obtaining the zero point, and is an adaptation of the gas analysis apparatus known as a "nitrometer," which is used for determining the volume of nitric oxide liberated during the analysis of nitrates. The briquette is placed in a reservoir containing mercury, which is connected by a piece of rubber pressure-tubing to a burette[1] having an enlarged end to receive a one-hole stopper. The mercury stands ordinarily at zero. When a briquette is introduced, it causes a rise in level in both the reservoir and the burette. The burette is then lowered until the mercury has resumed its former level. This is accomplished by having the burette mounted upon a sliding frame which is actuated by means of a rack and pinion. The lowering of the burette adds more glass tubing to the circuit, which, of course, takes care of the displaced mercury. The volume is then read directly from the burette. The top of the mercury meniscus forms an excellent mirror upon which to see the reflection of the zero point.

Construction.—The construction of the volumeter is not difficult and all of the material is at hand in nearly every labora-

[1] The burette is a graduated tube from Schumann's specific gravity bottle and reads from 0 at bottom to 50 at top. Cost about $3.50.

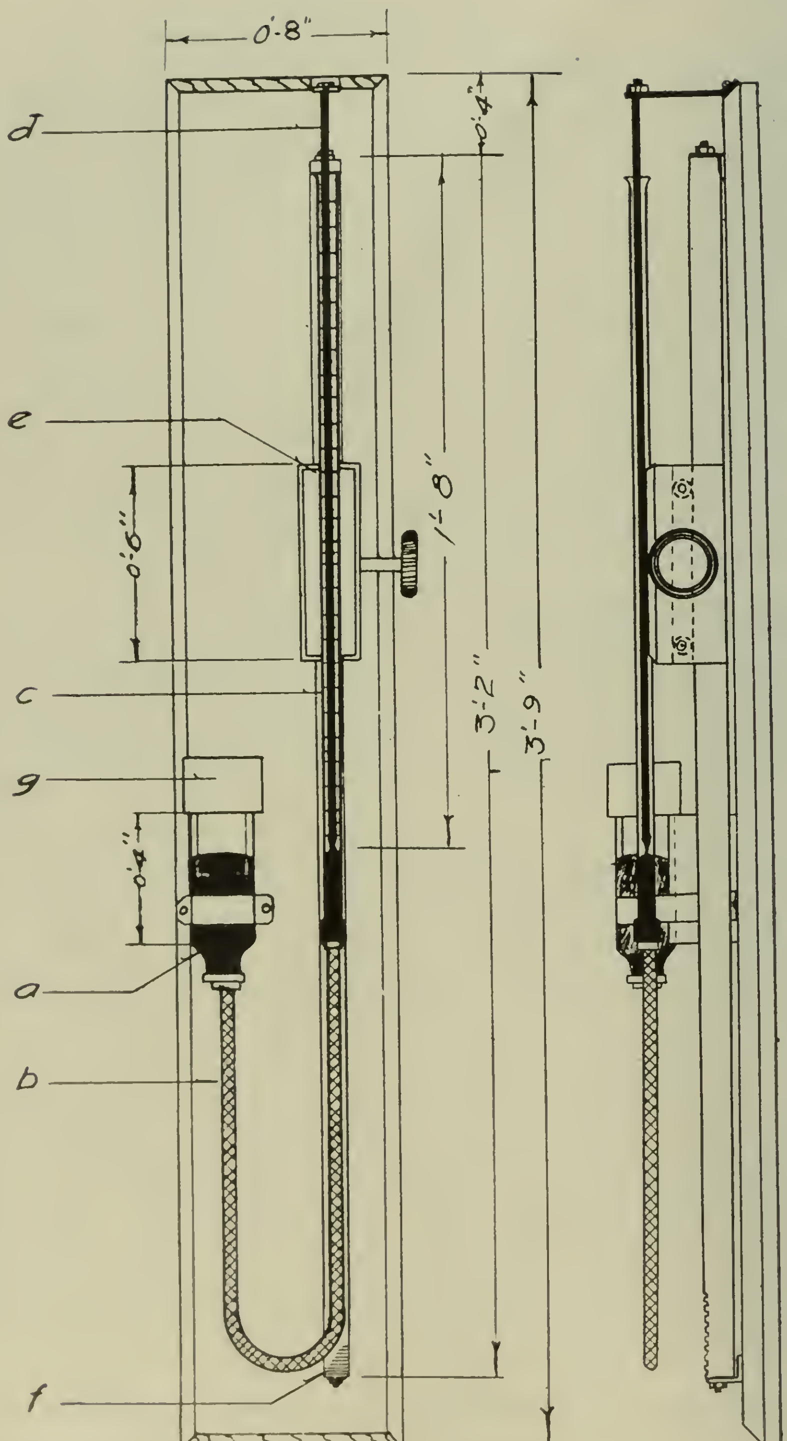


FIG. 1.

tory. The reservoir, "a" (Fig. 1), can be made from a tall, round or square bottle having a narrow neck. In this laboratory a reservoir made of glazed porcelain is being used. The diameter or width should be about $1^3/_4$ inches for standard dry test pieces. The bottom can be cut off by grinding on the edge of an emery wheel just above the seam between the bottom and sides. A rubber stopper is forced into the neck of the bottle and a 3-foot piece of rubber pressure-tubing, such as that used on suction apparatus, is attached by means of a short glass tube with a bulge at each end. The joint should be wired tightly and then waxed very securely. The other end of the tube is attached to burette "c" in a similar fashion. If a rack and pinion is to be used for raising and lowering the burette, the method shown in the drawing will be found very satisfactory.

In order to have a good, readable zero point, a pointed quarter-inch rod, "d," is bolted to the board by an iron brace and extends down inside the burette, ending at the zero point. This rod may be connected to one terminal of a bell circuit and the mercury made the other terminal, which will cause the bell to ring until the zero point is passed. However, with clean mercury, the end of the rod is reflected in the convex meniscus and the exact zero point is easily obtained.

Manipulation.—The manipulation is simple. First, after mounting solidly, the burette is raised until the lower end of the rod is exactly opposite the zero line on the burette. Then mercury is poured into the system until it touches the end of the rod, care being taken that the briquette holder is in place when the final adjustment for zero is made. The burette should then be run past this point several times in order to see that the mercury is running freely. Experience shows that on the first two or three trials one is apt to misjudge the point. However, when it has once been determined, there is no difficulty in duplicating it. The burette should always be raised in reaching the final adjustment in order to expose a clean and bright mercury surface.

The volumeter being ready for use, the briquette is placed in the holder, pushed under the mercury, and the burette then lowered until the point of the rod emerges from the mercury. The

setting is then readily obtained. The distance between the top of the mercury and the end of the rod is an indicator of the movement required for adjustment. Thus a difference of two-tenths of a cubic centimeter between the end of the rod and the top of the mercury requires about one centimeter movement of the burette. In regard to the setting of the zero point, this will have to be readjusted from time to time, either by adding a drop or two of mercury or by lowering or raising rod, "d." This is necessary after about every fifteen or twenty briquettes and may be readily checked by raising the burette to the zero point at fairly frequent intervals.

Tests of the New Volumeter

Mathematical Considerations.—The accuracy with which the volumes may be determined depends directly upon the ratio of the areas of reservoir and burette. Let us suppose that the area of the mercury surface in the reservoir is 16 sq. cm. and in the burette 1 sq. cm. Since area A times height H equals volume V, or,

$$\frac{V}{A} = H, \text{ then } \frac{V}{16 + 1} = H$$

Suppose that the volume V of the briquette is 25 cc. This volume is distributed throughout the system causing a rise of 25/17 or 1.47 cm. rise in each limb of the circuit. Hence, in a volumeter with the ratio of 16 to 1, the 25 cc. briquette would cause a rise of only 0.0587 cm. for each cc. of the briquette. With a reflection of the pointer, such as takes place in the mercury surface, it is possible to read to a much smaller length than 0.05 cm. However, let us use a volumeter with the ratio of 1 to 1. Then 25/2 or 12.5 cm. is the rise in each limb for the briquette. This is 0.5 cm. rise for each cc. of volume, or 0.05 cm. for each tenth cc. Extensive checking of the present instrument with a microscope-cathetometer showed unquestionably that the pointer may be adjusted with the naked eye to 0.003 cm. without fail. This corroborates observations by many physicists that the method of reflection reading of a point is extremely accurate.

These considerations must not be construed to mean that in reading the volume of a briquette with this mercury volumeter

one must estimate distances less than a tenth of a centimeter, for after the burette has been lowered or raised so that the mercury is at its original level, as when set at zero, *all* of the displaced volume of liquid is in the burette and the volume is read to tenths just as in the ordinary burette reading. But if in adjusting so that the reflection is just tipping the actual pointer, an error of

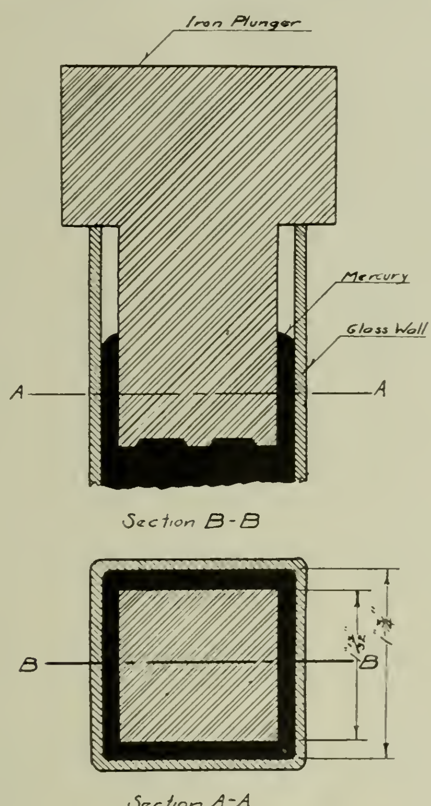


FIG. 2.

0.05 cm. is made, this will correspond to an actual error of 0.1 cc. in the briquette volume.

In order to obtain the ratio of approximately one to one for the area of the mercury reservoir to the area of the burette, it is necessary to reduce the area of free surface of mercury in the reservoir, since the cross section of the burette is necessarily fixed. This reduction is accomplished by using a heavy metal plug or plunger which has an area about one sq. cm. less than the reservoir. It is set so that it extends below the surface of the mercury when set at zero. When a bar of clay is introduced, the heavy metal plun-

ger keeps it from floating, and also confines the mercury surface to that which is free between the sides of the reservoir and the sides of the plunger (see Fig. 2). The bottom of the plunger is grooved to allow free access of the mercury above the briquette.

The question of expansion of the rubber tube, due to greater pressure caused by the increased length of mercury column when a briquette is placed in the reservoir, was answered in the following manner.

The diameter of the tube was measured by means of the cathetometer at three different points: four inches below each end, and at the lower point. A briquette of 47.0 cc. was then placed in the volumeter and the exact volume determined. The diameters were then re-measured at the same points. A maximum increase in diameter of one-fortieth of a millimeter was found at the lowest point in the tube, which may be reasonably attributed to experimental error or to increased pressure. Such an expansion throughout the total length of the tube would introduce an error of 0.005 cc. in the reading. A volume of 50.0 cc. of mercury at 13.2 gm. per cc. would weigh 660 gm. which would be distributed over the internal area of the rubber tube, or 2.03 gm./sq. cm., which is an insignificant increase in pressure for even thin tubing.

Comparative Tests.—In testing out this volumeter five burned briquettes were measured. Dry, or when saturated with water, the volumes were exactly the same. Then the saturated volumes were taken in an overflow type of volumeter using every care possible to avoid errors. The results checked within less than 0.05 cc. Plastic volumes were checked in a similar manner.

Then water was substituted for the mercury in the new volumeter, and the volumes re-determined. The same values were obtained as before. This indicates that for this purpose the action of the mercury in surrounding a briquette is the same as that of water. Finally, the volumes were measured by means of a Schurecht pycnometer and the results checked those of the mercury volumeter almost exactly.

Following this same line of reasoning, one could substitute mercury for water or kerosene in the overflow type of volumeter, and thus remove some of the draining difficulties. However, the refilling of the reservoir and setting to zero would still be necessary.

Laboratory Tests.—As an independent check, two graduate fellows from the Department of Chemistry in the University of Washington were asked to use this volumeter in determining the volumes of 200, 100, 50, 20, and 10-gram weights. The volumes were unknown to the operators and independent determinations were run. The actual volumes were determined by taking the weights in air and immersed in water, correcting for the volume of the wire support, and thus determinig their true volumes. This was done after the volumeter readings had been taken. The results follow.

Weight	200.00	100.00	50.00	20.00	10.00	Observer,
Reading	25.10	12.95	6.60	2.45	1.45	1
	25.10	12.95	6.50	2.45	1.45	1
	25.10	13.00	6.50	2.45	1.45	1
	25.15	13.00	6.55	2.45	1.45	2
	25.10	13.00	6.55	2.50	1.48	2
	25.10	13.00	6.50	2.45	1.45	3
	25.10	12.95	...	...	...	3
	25.10	13.00	...	...	...	3
	25.15	13.00	...	...	...	3
Mean	25.11	12.98	6.53	2.46	1.455	
Per cent variation	0.1592	0.2311	1.07	1.625	0.344	
Exact vol	25.150	13.001	6.53	2.475	1.40	
Per cent error	0.1590	0.1540	0.00	0.601	3.930	

The above results indicate that the volumeter is very consistent, for the variations were less than two-tenths of one per cent, even with different operators, while measuring volumes comparable with those of test clay briquettes, and finally, that for the volumes greater than 10 cc. the error of the mercury volumeter is less than two-tenths of one per cent based upon the true volumes as determined by loss in weight when immersed in water.

Summary

Disadvantages.—The disadvantages may be summed up as follows: (1) the initial cost of about two pounds of mercury; (2) slight tendency of mercury to remain in small holes and cracks of some briquettes, although it is readily shaken back into the

reservoir, and (3) a slight difficulty in obtaining readings for the first dozen determinations.

The precautions to be taken are these: Make absolutely rigid and tight connections with rubber pressure-tubing; use clean mercury, and check zero point after every few volume readings.

To clean mercury, it is only necessary to press it through the mesh of a clean handkerchief. Dust and dirt will float to the top of the mercury in the reservoir and can be easily blown off by means of a rubber tube and the breath. Occasionally the burette should be wiped clean by means of a burette brush, removal of the mercury during this operation not being necessary.

Advantages.—The advantages of this volumeter are as follows: (1) No twelve-hour soaking in kerosene is necessary for dry briquettes; (2) no draining of briquettes after immersion; (3) no draining of liquid; (4) it is direct reading; (5) it is very speedy and accurate; (6) no adjustment is necessary for every volume taken and when adjustment is required it is very quickly accomplished; (7) there is no adjusting of ground glass stoppers.

The writer wishes to acknowledge his indebtedness to Professor Hewitt Wilson, head of the Ceramics Department of the University of Washington and ceramist of the U. S. Bureau of Mines, for his interest and many helpful suggestions during the development of the volumeter, and also to Dr. H. V. Tartar, who kindly placed the physical chemistry laboratory of the University of Washington at the disposal of the writer for testing the volumeter.

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THE RELATION BETWEEN THE FINENESS AND OTHER PROPERTIES OF CALCINED GYPSUM[1]

By W. E. Emley and F C. Welch

ABSTRACT

Experimental methods.—The *normal consistency* was measured by the Southard viscosimeter, the *time of set* by the Vicat needle, and the plasticity by spreading upon a porous porcelain plate.

Conclusions.—(1) Normal consistency is obtained with less water the coarser the calcined gypsum, (2) the finer the material the shorter the time of set, (3) the finer the calcined gypsum the stronger is the set material until the degree of fineness beyond that of size 6 (A. S. T. M. spec.) after which increase in fineness is accompanied by decrease in strength, (4) the finer the calcined gypsum the more sand it will carry.

When attempting to prepare specifications for calcined gypsum, it was believed advisable to classify the material according to its fineness. Of course, fineness, *per se*, is of no great importance to the user. There are physical properties which are of importance to the user and for which no method of measurement has been definitely adopted. Experience seemed to indicate that these properties are more or less closely related to the fineness and that a measurement of the fineness would give some kind of an indication of the plasticity, sand carrying capacity, and similar properties. Unfortunately, no exact information was available as a basis for these relationships, and recourse was had to commercial conditions. Screening analyses were made of many samples of calcined gypsum, and the classification as to fineness was based upon these results.

This classification[2] states that calcined gypsum, "size No. 4," shall all pass an 8-mesh sieve (No. 8),[3] and not less than 40 nor more than 60 per cent of it shall pass a 100-mesh sieve (No. 100).

[1] Received Feb. 12, 1921. Published by permission of the Director, U. S. Bureau of Standards.

[2] A. S. T. M. Tentative Specification for Calcined Gypsum, C23–19T.

[3] Figures in parentheses refer to equivalent sieves of the U. S. Standard Sieve Series.

Size No. 5 shall all pass a 14-mesh sieve (No. 16), and not less than 60 nor more than 80 per cent of it shall pass a 100-mesh sieve (No. 100). Size No. 6 is such that all of it will pass a 28-mesh sieve (No. 30), and not less than 80 per cent of it will pass a 100-mesh sieve (No. 100).

Comparatively little calcined gypsum is used as such. Most of it goes into the manufacture of gypsum wall plasters and other gypsum products. It is desirable to know whether or not one or more of the sizes defined above is best adapted for a given purpose. Accordingly, a sample of calcined gypsum was screened to produce material of the three sizes listed, and each size was tested for normal consistency, time of set, tensile strength, combined water, plasticity, and sand carrying capacity. A fourth size was added, which we may call "No. 7," and define as such that all of the material will pass a 100-mesh sieve (No. 100). The first lot of calcined gypsum was unretarded; the entire series was repeated using retarded material.

Methods

Normal consistency is defined to mean the quantity of water (in cubic centimeters) which must be added to 100 grams of the calcined gypsum to produce a mixture which will have a consistency of 9.7 centimeters, when measured by the Southard viscosimeter.[1]

The time of set is the elapsed interval between the time when the sample is added to the water, and the time when a Vicat needle will no longer penetrate to the bottom of the pat. The ratio of water to sample is such as to produce a mixture of normal consistency.[2]

The tensile strength was measured by breaking three briquettes of the usual form. The briquettes were made of paste of normal consistency, and were stored in the air in the room until seven days old.

[1] A. S. T. M. tentative Methods for Tests of Typsum and Gypsum Products, C26–19T. See also Emley and Faxon, THIS JOURNAL, 4, 152 (1921).

[2] Emley, "Measurement of Time of Set of Calcined Gypsum," *Trans. Amer. Ceramic Soc.*, 1917, 573.

	Unretarded				Retarded			
Size No.	4	5	6	7	4	5	6	7
Per cent by weight passing 100 mesh sieve...	40	60	80	100	40	60	80	100
Normal consistency (cc. water).............	56.9	53.7	55.9	61.2	50.9	53.3	58	61.4
Time of set...........................	$10^1/_2$ m.	10m.	$10^3/_4$ m.	$8^1/_4$ m.	4h. 16m.	4h. 18 m.	3h. 5m.	2h. 46m.
Tensile strength (lbs. per sq. in.)...........	234	327	353	276	196	176	199	145
Combined water (per cent)................	5.11	5.59	5.49	5.46	8.71	8.60	8.01	9.02
Plasticity figure........................	122	99	113	98	107	114	94	89
Sand carry capacity (parts by wt.).........	1:3.2	1:3.8	1:2.5	1:4.3	1:1.3	1:1.7	1:2.6	1:3

By combined water, is meant that held by the gypsum or calcined gypsum as water of crystallization.[1]

The plasticity is measured by spreading a paste of normal consistency upon a porcelain plate of known absorptive capacity, at a constant rate.[2]

When increasing proportions of the calcined gypsum in a paste of normal consistency are replaced by equal weights of sand, the plasticity figure of the mixture decreases, approaching that for sand. When the figure has decreased to a certain predetermined minimum, the ratio of calcined gypsum to sand is taken to be the sand carrying capacity of the calcined gypsum. Using the commercial plastering sand of Washington, measurements were made for each ten per cent variation in composition from 100 per cent calcined gypsum to 100 per cent sand, and the figures given were determined by interpolation.

Results

The experimental results are shown in the table on preceeding page.

Conclusions

It is dangerous to attempt to draw conclusions from such a small amount of data; it is safer to call the following "indications" rather than conclusions.

The finer the calcined gypsum, the more water will be required to make a paste of normal consistency. This statement is logical, and is borne out by the results obtained from the retarded material. The discrepancies shown by the unretarded sample are not explained. Size 7 of this sample follows the above rule.

The finer the calcined gypsum, the more quickly it will set. This statement is also logical, and is borne out by both sets of data. Within the limits of the specifications, however, the fineness does not have much influence on the time of set.

The tensile strength of the unretarded material brings out an

[1] For the method of determination, see A. S. T. M. specification C26–19T. It consists of noting the loss of weight when the material is dried for two hours at 45°C.

[2] Emley, *Measurement of Plasticity of Plasters and Mortars*, Bureau of Standards Tech. Paper No. 169.

unexpected fact: It seems logical to suppose that the finer the calcined gypsum, the more completely will it react with water, and therefore the stronger the set material should be. On the other hand, it is known that the finer material will require more water, and that this extra water may be regarded as a source of weakness. The results indicate that, within the specifications, the former factor is predominant; that increased fineness of the calcined gypsum is accompanied by increased strength of the set material. When, however, the calcined gypsum is finer than that recognized by the specifications, the amount of mixing water becomes the predominant factor. Any increase in fineness beyond that defined as class 6 is apparently accompanied by a decrease of strength.

It has frequently been stated that a given material is most plastic when it is neither too fine nor too coarse, but is composed of fine and coarse particles in their proper proportions. The plasticity figures given for the retarded material seem to indicate that there is some foundation for this statement. The discrepancies shown by the unretarded sample, both in plasticity and sand carrying capacity, can probably be explained by the fact that the setting reaction had attained a measureable velocity before the plasticity determination was complete.

The finer the calcined gypsum, the more sand it will carry. The truth of this statement is generally accepted, and is plainly indicated by the tests of the retarded material. If it is true, as is indicated above that the condition for maximum plasticity is a definite relation between the amounts of coarse and fine material, it seems obvious that when a material is too fine for maximum plasticity, the addition of a certain amount of sand will tend to improve the plasticity by restoring the proper balance between fine and coarse particles. The finer the material, the more sand will be required for this purpose.

CERAMIC ABSTRACTS

Author Index[1] to Abstracts for April

[1] The abbreviation (C. A.) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. Graphical methods of computing the composition of ceramic bodies. U. PFAFF AND M. DONATH, Porcelain Factory, Freiberg in Saar. *Ber. d. Deut. Keram. Gesell.*, 1, Pt. 2, 21–32 (1920).—Figure 1 represents the rational

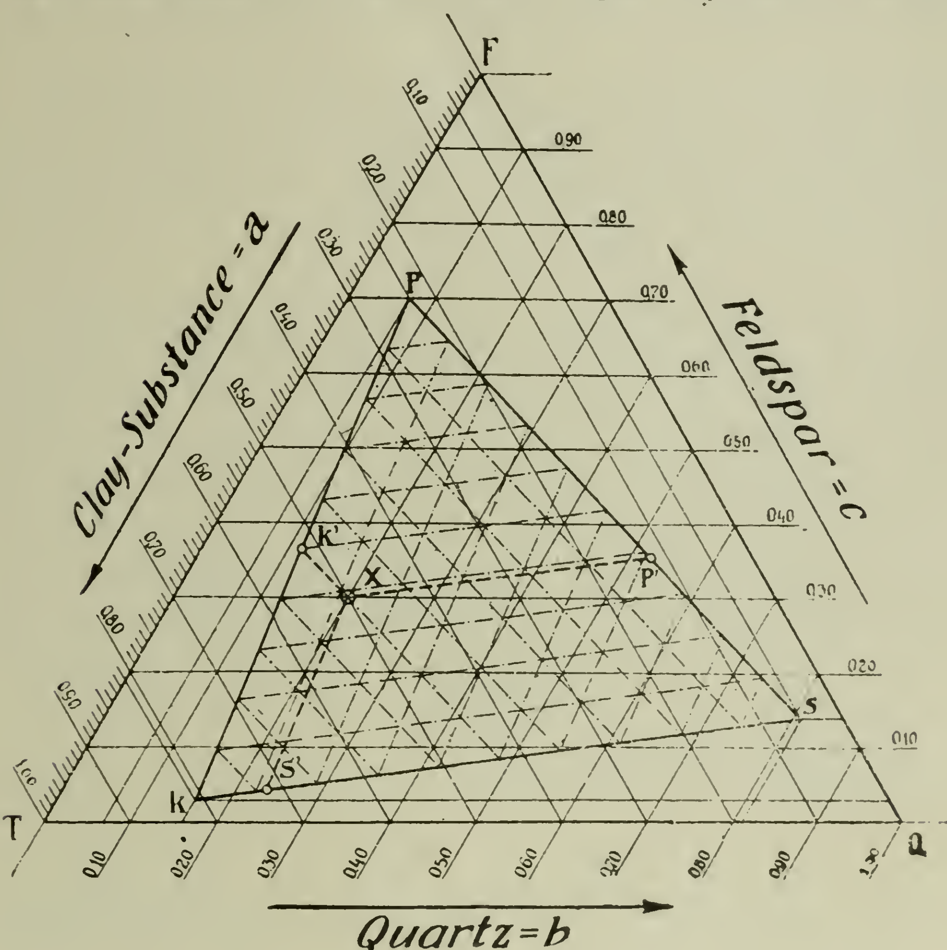

FIG. 1

composition of a clay, a sand, and a feldspar in terms of kaolin, quartz, and feldspar. The clay has the composition shown by point K, the sand by S, and the feldspar by P. It is desired to find in what proportions to mix the clay, sand, and feldspar to give a body having the composition represented by the point X. From the point X, lines are drawn, XK′, XP′, XS′, parallel to the sides of the triangle KSP. The fraction K′P/KP = fraction of clay, S′K/SK = fraction of sand, and P′S/PS the fraction of feldspar to be used to give the body represented by point X. Only bodies represented by points within the triangle KSP can be prepared from the three materials, K, S, and P. The body X could also be obtained from a mixt. of S. and P with another material K, by a similar procedure. Let $a + b + c = 1$ be the fractions of

K, S, and P required, and $a_1 + b' + c' = 1'$ be the fractions of K_1, S and P required to give X, then a mixt. of m parts of 1 with $(1 - m)$ parts of $1'$, giving a mixt. also with the composition X will contain $(m \times a)$ parts of material K,

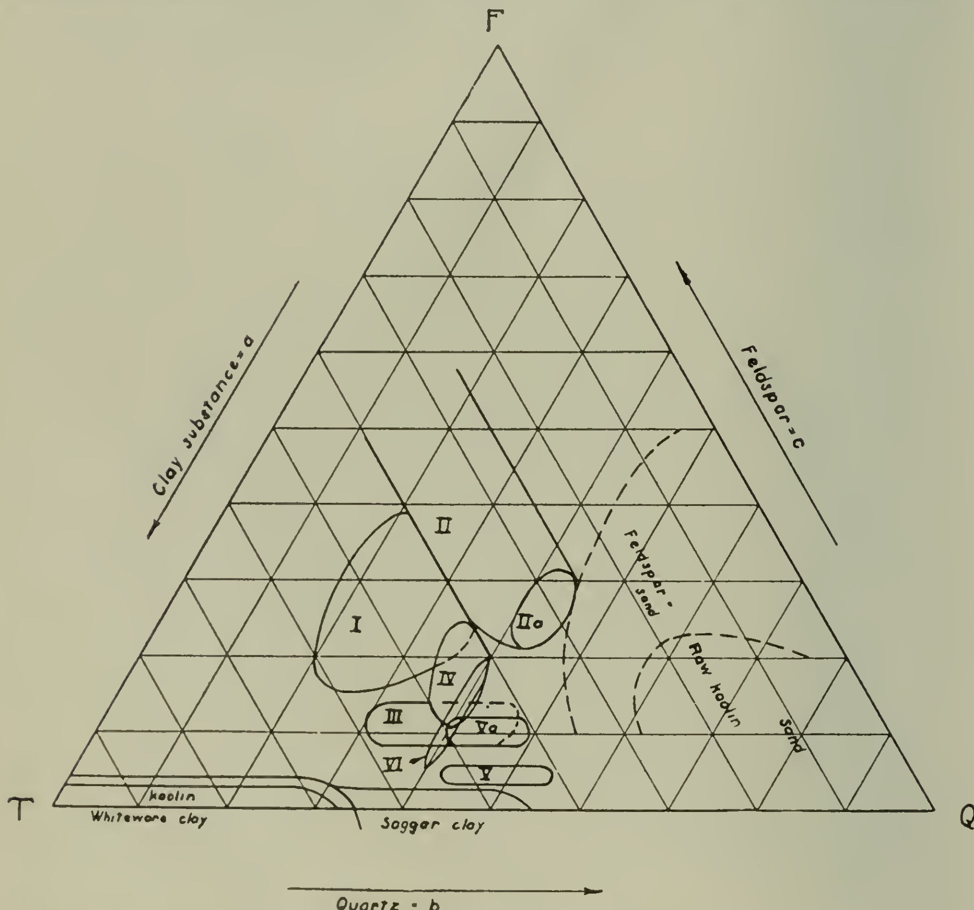

FIG. 2.—I, Hard porcelain; II, soft porcelain; IIa Japanese porcelain; III, semi-porcelain; IV stoneware; V, whiteware; Va, new German vitreous whiteware; VI, calcareous whiteware.

$[(1 - m).a_1]$ parts of K_1, $[m(b - b') + b']$ parts S, and $[m(C - C') + C']$ parts P. A rational composition diagram of several porcelain and stoneware bodies is given in figure 2. E. N. BUNTING

2. **Modern commercial explosives and their uses.** A. J. STRANE. *Trans. Am. Inst. Mining Met. Eng.*, **1920**, 7 pp. (advance copy).—S. describes nitroglycerin, blasting gelatin, straight nitroglycerin dynamites, straight gelatin dynamite, extra, or ammonia, dynamites and gelatin, low-freezing nitroglycerin explosives, permissible explosives, non-freezing explosives and black blasting powder, giving in general the compn., properties and form of commercial packages. CHARLES E. MUNROE (C. A.)

3. **Schedule of fees for consulting engineers.** Edmund I. Mitchell. *Mining & Metallurgy,* **169,** 15–17 (1921).—A summary and bibliography of the information on this topic which has been published in technical journals during the past ten years. C. W. Parmelee

4. **The engineering profession and government technology.** R. S. McBride. *Chem. Met. Eng.,* **23,** 1265–7 (1920). E. J. C. (*C. A.*)

5. **Lubricants and lubrication.** Anon. *Chem. Trade J.,* **67,** 769–70 (1920).—The report of the Lubricants and Lubrication Inquiry Committee issued by the Advisory Council of the Department of Scientific and Industrial Research is reviewed and a list of 13 recommendations for future research is given. Eugene C. Bingham (C. A.)

Patents

6. **Treating clays.** W. Smith. Brit. 149,440, May 13, 1919. In the production of articles and materials from clay, the clay is heated together with a material containing volatile C compds., such as bituminous or oil shale, with the exclusion of air, the excess C being left within the mass of the article. The clay may be impregnated with volatile C compds., or the biscuited articles may be charged with gaseous or liquid carbonaceous compds. and heated with the exclusion of air. The firing may be effected by embedding the clay article in powdered coke or oil shale, and the temp. used may be sufficient to seal up the C in the clay. The carbonized clay may be treated with clay slips, glazes, or enamels. *Abrasives* may be formed by satg. clay with C as above, heating to a very high temp., say 1600°, and grinding the material (C. A.)

Books

7. Hacker, W.: **Handbuch der Kitte und Klebemittel.** Meissen: Math. Bohlmann. 161 pp. M. 15. (C. A.)

8. Lassally, A.: **Bild und Film im Dienste der Technik. Part I. Betriebsphotographie.** 118 pp. M. 5.30, bound M. 6.30. **Part 2. Betriebskinematographie.** 247 pp. M. 12.60, bound M. 13.85. For review see *Z. ver. deut. Ing.,* **64,** 1094 (1920). (C. A.)

9. Lockhart, L. B.: **American lubricants.** 2nd Ed. revized and enlarged. Easton, Pa.: The Chemical Publishing Co. 341 pp. $4.00. For review see *Am. J. Sci.,* **1,** 89 (1921). (C. A.)

10. Pascal, Raoul: **Synthèses et catalyses industrielles.** Lille: G. Janny, 4, place Philippe-Lebon. 238 pp. For review see *Ind. chim.,* **7,** 376 (1920). (C. A.)

11. **Rept. of the Lubricants and Lubrication Inquiry Comm. Advisory Council Dept. of Scientific and Industrial Research.** London: H. M. Stationery Office. 2s. 6d. (C. A.)

12. Schmidt, O.: **Chemie für Technicker. Leitfaden für Maschinen- und Bautechniker.** 8th Ed. revized. Stuttgart: Konrad Wittwer. M. 7. (C. A.)

13. Thompson, W. P.: **Handbook of Patent Laws of All Countries.** 18th Ed. revized. London: Stevens & Sons, Ltd. 157 pp. 6s. For review see *Nature*, **106**, 275 (1920). (C. A.)

14. Thomsen, T. C.: **The Practice of Lubrication.** New York and London: McGraw-Hill Book Co. 607 pp. $6.00. For review see *Proc. Am. Soc. Civil Eng.*, **46**, 879 (1920). (C. A.)

15. **Tonindustrie-Kalender 1921** (in 2 parts). Berlin: Verlag der Tonind. Ztg. G. m. b. H. M. 8.50 for both parts. For review see *Tonind.-Ztg.*, **44**, 1287 (1920). (C. A.)

16. Dolt, M. L.: **Chemical French.** Second Ed. Easton: The Chemical Publishing Co. 413 pp. $4. For review see *J. Phys. Chem.*, **24**, 754 (1920). (C. A.)

Apparatus and Instruments

17. **Methods for the production and measurement of high vacua.** S. Dushman. *Gen. Elec. Rev.*, **24**, 58–68 (1921).—Discussion of the absorption of gases by charcoal and Pd black. C. G. F. (C. A.)

18. **Apparatus for grinding rock specimens.** A. Hadding. *Geol. För. Förh.*, **42**, 378–83 (1920).—An app. tested at Lunds Geologisk-Mineralogiska institution filled these requirements satisfactorily: several specimens of varying thickness could be prepd. at the same time, each specimen finished could be easily removed and another put in its place without stopping the grinding of the other specimens, the grinding of each specimen was automatically stopped when the specimen reached a predetd. thickness, the app. could be left running without attention, and it was moderately simple and inexpensive. Two cuts and 1 diagram explain its construction clearly. The rock specimens are fastened with wax to the bottoms of 8 rock holders (Fe disks with shafts) held in the periphery of a circular metal plate properly supported above a rotating cast-iron plate onto which water and carborundum powder are fed. Springs hold the specimens, both thick and thin, against the plate with equal pressure. A special device prevents individual specimens from being completely ground away although the app. is still running. The rotating plate may be driven by an electric motor or by hand or foot power. It is recommended that the app. be used for rough grinding and that the final fine grinding be done by hand. Wilhelm Segerblom (C. A.)

Books

19. Marr, Otto: **Das Trocknen und die Trockner.** 3rd Ed. enlarged by Karl Reyscher. Berlin: R. Oldenbourg. 544 pp. M. 60, bound M. 65. (C. A.)

20. METZ, CARL AND HAGER, HERMANN: **Das Mikroskop und seine Anwendung. Handbuch der praktischen Mikroskopie und Anleitung zu mikroskopischen Untersuchung.** 12th Ed. revized. Berlin: Julius Springer. M. 38. For review see *Chem.-Ztg.*, **44**, 855 (1920). (C. A.)

21. EVENS, EDMUND M.: **Pumping by Compressed Air.** New York: John Wiley & Sons, Inc. 266 pp. $4.00. For review see *Proc. Am. Soc. Civil Eng.*, **47**, 948 (1920). (C. A.)

Chemistry, Physics and Geology

22. **A capillary phenomenon.** H. BECHHOLD. *Kolloid.-Z.*, **27**, 229–33 (1920).—On attempting to impregnate porous cells (unglazed porcelain, burned kieselguhr) with an insol. ppt. produced, *i. e.*, by the interaction of $AgNO_3$ with KCNS or of $CuSO_4$ with NaOH, it was found that the reaction product was concd. mainly in the exterior layer of the cell wall, although one salt was uniformly distributed initially by soaking the cell in its soln. The phenomenon seems to be a general one. Ordinary garden earth when wet with solns. of NaCl, $BaCl_2$, and $Al_2(SO_4)_3$ and then allowed to dry slowly, showed enormous concn. of the salts in the upper layers. The importance of the phenomenon in relation to *efflorescence on brick-work* was discussed. The theory is being investigated, the most probable explanation being the growth of larger crystals at the expense of smaller ones. J. A. (C. A.)

23. **Aluminates of sodium. Equilibria in the system Na_2O–Al_2O_3–H_2O** F. GOUDRIAAN. *Proc. Acad. Sci. Amsterdam*, **23**, 129–42 (1920). (C. A.)

24. **The arsenites of lithium and potassium.** F. A. H. SCHREINEMAKERS AND MISS W. C. DE BAAT. Univ. Leyden. *Rec. trav. chim.*, **39**, 423–8 (1920). (C. A.)

25. **Hydrolysis of the silicates of sodium.** R. H. BOGUE. *J. Am. Chem. Soc.*, **42**, 2575–82 (1920).—H-ion concns. were measured at 30° of solns. $^1/_3$, 0.1, 0.05, 0.02 and 0.01 molar of 7 silicates in which SiO_2/Na_2O varied from 4/1 to 1/1. The data indicate either that these silicates are much less hydrolyzed in dil. soln. (1.58–28.43% in 0.01 molar soln.) than has been supposed or else that the electrometric method is unsuitable for measuring such dissocn., possibly because colloidal SiO_2 is able to adsorb or retard OH ion. The data confirm Na_2SiO_3 to be most hydrolyzed and the degree of hydrolysis to decrease as more SiO_2 is added to the mol. A. R. MIDDLETON (C. A.)

26. **The system cupric oxide, cuprous oxide, oxygen.** F. H. SMYTH AND H. S. ROBERTS. *J. Am. Chem. Soc.*, **42**, 2582–2607 (1920).—Solid soln. of of Cu_2O in CuO does not take place in the temp. range where both oxides remain solid. The pressure temp. equil. curves have been established over the range in which the oxides remain solid, below the eutectic pt., and above the eutectic pt. where CuO remains the solid phase, up to 1233°. The quadruple point lies at 1080.2° and 390 mm. Pure CuO does not melt without

dissocn. below 1233°. The general direction of the equil. curve is indicated for the system when Cu_2O remains the only solid phase and the theoretical deduction is confirmed that the equil. pressure drops with rise of temp.

A. R. MIDDLETON (C. A.)

27. **The solubility of metals in acids containing formaldehyde.** R. C. GRIFFIN. *J. Ind. Eng. Chem.*, 12, 1159–60 (1920).—Exptl. results are tabulated which show the inhibitory effect upon the soln. of metals by mineral acids caused by the presence of HCHO. This effect is marked in the case of ferrous metals. A practical application in the use of HCl containing 1% HCHO, which secures pickling of rusty steel without appreciable effect upon the steel itself.

W. H. BOYNTON

28. **Graphite deposits in Siberia.** ANON. *J. Roy. Soc. Arts*, 68, 442 (1920).—Extensive deposits of graphite exist on the left bank of the River Kureika, near its junction with the Yenisei. The graphite area forms a horizontal plateau, the elevation of which varies from 20 to 50 feet above the normal level of the Kureika. The plateau contains two layers of graphite, of a solid steel-grey color, soft, and of an excellent quality for the manufacture of pencils. Analysis: 89.51% C, 0.60% H, and 9.89% residue. The graphite is not inflammable and is very plastic. The color constituent is said to be of superior quality.

J. L. CRAWFORD

29. **Chrome ore deposits in Asia Minor.** ANON. *J. Roy. Soc. Arts*, 68, 564–67 (1919).—The chrome producing districts of Turkish Asia Minor are classified in four zones: Brusia, Smyrna, Adana, and Konia. Brusia Province produces 10,000 to 15,000 tons of high grade (44–55% Cr_2O_3) ore annually, Smyrna 7,000 to 15,000 tons (40–55% ore), Adana 1,000 tons (50–51% Cr_2O_3) and Konia 1,000 tons. Transportation and mining methods are primitive.

J. L. CRAWFORD

30. **The basalts of the "Blaue Kuppe bei Eschwege" and adjacent occurrences, and their cristobalite.** PAUL RAMDOHR. *Centr. Min Geol.*, 1920, 33–6.—R. describes the cristobalite in detail. Crystals are generally smaller than 1 mm. and milky white. They occur in 3 habits: (1) Well shaped octahedra; (2) 6-sided plates; and (3) crystals that are geometrically identical with tridymite. All become isotropic at 235–250°C.; d. = 2.290–2.320, n = 1.485; birefringence = 0.0018. There are all transitions between habit 1 and 2, the latter being the commoner. The transitions, as well as twinning according to the spinel law, indicate that habit 2 represents distorted octahedra. There are also transitions between habits 2 and 3 and closer investigation of the apparent hexagonal prisms reveal that they are built up by a oscillatory combination of the octahedron and cube. Interpenetration twins of the tridymite type after (1016) and (3034) also occur and are shown to be due to distortion of different octahedral faces of two octahedrons in parallel position.

OTTO VON SCHLICHTEN (C. A.)

31. **Potash in New Jersey Greensands.** George R. Mansfield. *Mining & Metallurgy*, **169**, 28–29 (1921).—An abstract. The U. S. Geol. Survey and the N. J. Dept. of Conservation and Development in a joint investigation of borings and well drillings for five selected areas in the southern half of the State, estimate the average content of potash in the greensand, its tonnage and its value. Mention is made of the four companies engaged in producing potash and the nature of their products, also of the utilization of greensand in the manufacture of *cement* and the recovery of the potash from the flue dust.

C. W. Parmelee

Books

32. Spurr, J. E.: **Political and Commercial Geology and the World's Mineral Resources.** N. Y.: McGraw-Hill Book Co., Inc. 561 pp. $5.00.

(C. A.)

33. **Gypsum in 1919.** Ralph W. Stone. U. S. Geol. Survey. *Mineral Resources of U. S.*, 1919, Pt. II, 99–113 (Preprint No. 8, publ. Dec. 28, 1920).

E. J. C. (C. A.)

34. Logan, W. N.: **Kaolin of Indiana.** Indianapolis: The Dept. of Conservation, State of Indiana, Division of Geology. 132 pp. For review see *Chem. Met. Eng.*, **23**, 1138 (1920). (C. A.)

Refractories and Furnaces

35. **Heat losses through electrodes in electric furnaces.** Frank Hodson. *Iron Age*, **106**, 1262–3 (1920). C. G. F. (C. A.)

36. **Electric furnace usage fast increasing.** Anon. *Elec World*, **77**, 77–9 (1921).—A short review of the electrochem. and electrothermal industries during 1920. C. G. F. (C. A.)

37. **The present status of the electric furnace in the American metal industries.** Robert M. Keeney. *Chem. Met. Eng.*, **23**, 980–4 (1920).

(C. A.)

38. **Electric versus combustion furnaces for low temperatures.** Frank W. Brooke and Geo. P. Mills. *Chem. Met. Eng.*, **23**, 1008-10 (1920).—The more recent com. applications of elec. energy to low temp. work (up to 1000°) are discussed. The advantages of elec. heat over that from combustion are summarized as: (1) Absolute control of temp; (2) saving in labor (no handling of coal, ashes, oil, etc.); (3) upkeep cost inconsiderable; (4) smaller space required; (5) reduction of rejections in finished product; (6) improved product; (7) ideal shop conditions. The items of temp. control, first cost, maintenance, and cost of operation are considered separately and it is shown that, all things considered, the elec. furnace is frequently the most economical installation.

W. E. Ruder (C. A.)

39. **Comparative heat efficiency of generator-gas firing and pulverized-coal firing.** E. Terres. *J. Gasbel.*, **63**, 673–5 (1920).—The comparative

thermal efficiencies of gas firing and pulverized-lignite firing are 53.29% and 75.73%, the difference being the heat required to convert the lignite into gas.

J. L. Wiley (C. A.)

40. **The addition of carbonic acid gas to the generator process.** O. Essich. *Feuerungstechnik*, 8, 184–5 (1920).—Attempts at solving the problem of improving the generator process in past years resulted mostly in failures (of records of these attempts see Fischer's Year Book 1890, p. 190 and 1893, p. 233).—The increasing price of fuel demands the solution of the problem. There is no doubt that there is a certain amt. of advantage in the addition of furnace gases containing CO_2 to the vaporization atm. E. discusses advantages and disadvantages of the process and offers suggestions for suitable expts. The following advantages are anticipated: (1) Greater evolution of gas per kg. of fuel; (2) reduction of steam demand; (3) consequent reduction of steam production; (4) better adaptation of the gases for metallurgical purposes (Martin furnace); (5) production of warm waste gases by the addition of hotter waste gases. At generator temp. of 500–1000° there is an addition of 1 cc. CO_2 gas to 5 cc. O, both entering at same temp. The waste gases are hot and theoretically the CO_2 content of the mixt. can be increased up to 0.5% for each 100° temp. of waste gases. A disadvantage is the danger that through lowering of temp. in the generator chem. equil. will be shifted and a higher CO_2 content will appear in the gas. Only a moderate CO_2 increase, however, is anticipated. It is pointed out that the CO_2 addition must be const. The addition of waste gases is not permissible in the reduction zone but must be made in the upper half of the combustion chamber.

H. C. Parish (C. A.)

41. **Possibilities for research and development in the field of refractories.** Homer F. Staley. *Chem. Met. Eng.*, 23, 1167–71 (1920).—The annual production of refractories in the United States is about $72,000,000. Fire-brick have an annual value of $36,000,000; silica brick of $20,000,000; magnesite refractories of $6,500,000. Under existing conditions research of great monetary value must lie in the field of these three. Economic considerations rather than lack of technical skill and knowledge limit the field of research and prevent the development of new refractories. Among commercially feasible possibilities are the more extended use of sillimanite refractories, of the diaspore clays and of magnesium spinel. For special purposes the use of carborundum, fused alumina and zirconia refractories should be developed. As a rule refractory coatings on less refractory foundations are not satisfactory. An extension of the use of heat insulating materials may result in a radical change in the use of refractories. The development of an insulating material that will not shrink at maximum furnace temperatures would bring about drastic changes in the design of electric furnaces. A. J. Lambert

Patents

42. **Alumina.** J. Morel. Brit. 149,769, May 17, 1919. Al_2O_3 is obtained from bauxite or other aluminous material by furnacing the latter in the pres-

ence of SO_2, air and steam, lixiviating the product, and then decomposing the resulting ferruginous soln. of $Al_2(SO_4)_3$ by means of $Na_2S_2O_3$ according to the equation $Al_2(SO_4)_3 + 3Na_2S_2O_3 = Al_2O_3 + 3SO_2 + 3S + 3Na_2SO_4$. The ppt. of Al_2O_3 and S is calcined to produce pure Al_2O_3 and SO_2. In order to make the process cyclic, the SO_2 from this source, as well as that evolved according to the equation, may be utilized both for the furnacing operation and for the regeneration of the $Na_2S_2O_3$. The latter is prepd. by evapg. to dryness the soln. of Na_2SO_4 which remains after filtering off the Al_2O_3 and S, reducing the sulfate to sulfide by means of C, and then passing air and SO_2 into the aq. soln. of Na_2S. If the process is not intended to be cyclic, the S is sepd. from the pptd. Al_2O_3 by distn. or dissolution. To facilitate the furnacing operation, the gases may be passed over a catalyst such as Fe_2O_3; or a catalyst, such as Al or other chloride, may be added to the bauxite. (C. A.)

Books

43. Booth, W. H.: **Fuel Economy.** 2nd Ed. revized. London S. Rentel. & Co., Ltd. 92 pp. 2s. 6d. net. For review see *Tech. Review*, 6, 777 (1920). (C. A.)

44. Fischer, Ferd: **Taschenbuch für Feuerungstechniker.** 8th Ed. newly edited by Fr. Hartner. Stuttgart: A. Kröner. 320 pp. M. 12, bound M. 16. (C. A.)

45. Gibson, Walcot: **Coal in Great Britain.** London: Edward Arnold. 311 pp. 21s. (C. A.)

46. Herington, C. F.: **Powdered Coal as a Fuel.** 2nd Ed. revized. New York: D. Van Nostrand Co. 338 pp. $4.50. For review see *Proc. Am. Soc. Civil Eng.*, 46, 947 (1920). (C. A.)

47. Le Chatelier, Henry: **Le chauffage industriel.** Paris: Dunond. 536 pp. 36 fr. (C. A.)

48. **Report of the Fuel Research Board for Years 1918 and 1919.** London: Dept. of Scientific and Industrial Research by H. M. Stationery Office. 1s. 6d. For review see *Tech. Rev.*, 7, 380 (1920). (C. A.)

See also Abs. Nos. 28, 29.

Abrasives

Patent

49. **Alumina; abrasives.** Carborundum Co. Brit. 150,116, June 18, 1919. A fused Al_2O_3 for abrasive purposes, containing from 0.2–1.3% of TiO_2 and less than 0.8% each of Fe_2O_3 and SiO_2, is obtained by fusing in an elec. furnace a mixt. of aluminous material such as bauxite, clay, emery, etc., with enough C to obtain a product containing 90% of Al_2O_3, cooling, crushing, sepg. metallic particles, and again fusing the product with a small quantity of C sufficient to obtain the further reduction of impurities necessary to ob-

tain the production of the above-stated compn. Instead of using for the second fusion the product obtained by the first described treatment, waste or dust from Al_2O_3 which has been fused for abrasive purposes may be used, but in all cases C is employed in the final fusion. The product is used for abrasive purposes such as grinding wheels, and is preferably agglomerated by ceramic material. A suitable compn. is abrasive grains 80%, Albany clay or other fusible clay 14%, stoneware clay 5%, and feldspar 1%. This mixt. is burnt at 1350°. (C. A.)

See also Abs. No. 6.

White Ware and Porcelain

50. (Porcelain) insulation for high voltage transmission systems. ALFRED STILL. *Elec. Rev.*, **78**, 54–7 (1921).—In this instalment the fundamental laws of the dielec. circuit, dielec. strength of insulating materials, effect of condensers connected in series and the pin type insulator, are discussed.

C. G. F. (C. A.)

See also Abs. No. 57.

51. Pottery Industry of Swatow. ANON. *J. Royal Soc. Arts*, **69**, 18–19 (1920).—Chinaware, both coarse and fine, and pottery and earthenware, are made in Swatow, China, to supply a large portion of the local requirements, and are exported to the South Seas, the Strait Settlements, and Siam. The methods of manufacture are primitive and much of the chinaware is of inferior quality. J. L. CRAWFORD

52. Japanese Pottery industry. ANON. *J. Royal Soc. Arts*, **68**, 716–18, 730–31 (1919).—The value of the porcelain and earthenware produced in Japan in 1918 was 44,214,084 yen (approximately £4,500,000). The relative production of the different classes of pottery for 1917 was as follows: Ornaments and art objects, 18%, dishes 56%, industrial goods 10%, toys 5%, miscellaneous, 11%. During the war the exports of pottery increased until the amount for 1918 had grown to four times the figure for 1914. The following classes of porcelain and semi-porcelain products, which are produced in quantity, enter largely into the export trade Tableware, sanitary ware, electrical porcelain, toys and novelties. A description of the industry is given.

J. L. CRAWFORD

Glass

53. Glass and some of its problems. SIR HERBERT JACKSON. *J. Royal Soc. Arts*, **68**, 134–46 (1920).—A popular lecture on glass and its manufacture. Among the topics discussed the following may be mentioned: The viscosity of glass at low temperatures; vitreous arsenic trioxide, sulphur, aqueous sodium acetate, aqueous Rochelle salt and zinc silicate; the effect of dissolved gases and other influences upon the devitrification of glass; the vitrifying influences of the oxides of Ti, Zr, Sn and Th; the production of opal glasses; the manufacture of colored glasses; and the behavior of MnO_2 in glass. Ed.

PATENTS

54. **Mixing or comminuting and dissolving alkali silicates.** F. J. PHILLIPS and E. J. ROSE. Brit. 151,508, Nov. 28, 1919. In mixing or comminuting and dissolving alkali silicates by agitating the partially disintegrated silicate in the presence of H_2O under the action of steam or gas in a rotary mixer, the steam or gas is arranged to be directed in the form of jets throughout the whole internal space of the mixer and to impinge with force upon the particles of the material treated. A suitable construction is specified. (C. A.)

55. **Acid-proof buildings and structures.** P. L. PFANNENSCHMIDT. Brit. 149,667, July 30, 1920. H_2SO_4 chambers or towers or any other structure for holding or conducting acid gases, are formed of a rigid acid-proof window-shaped framework in which are inserted sheets of acid-proof material such as quartz glass, enamel metal or glass. When using quartz-glass plates, a damaged plate may be mended by sticking a piece of quartz glass over it with water-glass putty. A suitable construction is specified. (C. A.)

56. **Investigation of crystal structure by the Debye-Scherrer method.** N. GROSS. *Umschau*, 34, 510–4 (1920).—G. describes in a semi-popular article an app. for the investigation of crystal structure by means of X-rays on crystal powder. Quartz glass and gelatinous SiO_2 proved to be amorphous Cf. Hull, *C. A.*, 12, 649. OTTO VON SCHLICHTEN

See also Abst. Nos. 25, 26.

Enamels

57. **Commercial photometry.** A. L. POWELL AND J. A. SUMMERS. *Gen. Elec. Rev.*, 24, 50–8 (1921).—A review. A very useful bibliography is appended. C. G. F. (C. A.)

PATENTS

58. **Protective treatment of iron blast furnace tuyères.** SCHUSS GEBR., DAMPFKESSEL- UND APPARATE-BAUANSTALT. Ger. 319,938, May 31, 1918. The castings are coated with a highly refractory enamel. Any liquid Fe falling upon this surface flows off readily. (C. A.)

See also Abst. Nos. 27, 31, 55.

Cement, Lime and Plaster

59. **Gypsum—properties, definition and uses.** Bur. of Standards, *Circ.* 108.—The uses of gypsum are discussed under the headings: Portland cement, fertilizers, plaster of Paris, wall, potter's and dental plasters, plate glass, cold-water paints, wood-fibered plaster, tile, plaster board, wall board, and Keene's cement. Recommended specifications for calcined gypsum, neat gypsum plaster, gypsum plaster board, and gypsum wall board are given in full.

A. J. LAMBERT

60. **Fused cements and the electric furnace.** J. BIED. *Rev. l'ingénieur*, 27, 191–3 (1920).—Fused aluminous cements have approx. the formula:

$SiO_2.2CaO + 2(Al_2O_3.—CaO)$. These cements react to a very slight extent with sulfate waters. After 72 hrs. the strength of the mortar is equal to that of any artificial cement after three months. The curve of hardening of cement is not a parabola as is commonly assumed. (C. A.)

Patents

61. **Slaking lime in a vertical container.** C. E. CANDLAT. Ger. 323,519, Sept. 26, 1913. The H_2O used for slaking the lime is introduced within the CaO mass itself and in an amt. which corresponds to the lime discharged from the container. (C. A.)

62. **Lime and like kilns.** W. SOMERVILLE. Brit. 150,157, July 23, 1919. A lime or like kiln is provided with air inlets above the fire and with one or more uptakes communicating with the interior of the kiln below the burning zone, the draft being downwards, while the CO_2 or other gases pass away through the uptakes, draft being induced by air which enters at the foot of the kiln and is heated by the hot lime before entering the uptakes. Induced or forced draft may be used to assist in carrying off the CO_2. A suitable construction is specified. (C. A.)

63. **Slag cements.** R. BOVEROULLE. Brit. 149,988, Aug. 9, 1920. In making cement from slag by the cold process, lime dross, consisting of the residue of the lime which has passed through the grids beneath the kilns, together with ashes of the fuel employed, is mixed with granulated slag. (C. A.)

Books

64. FRITSCH, J.: **Fabrication du ciment.** 2nd Ed. revized. Paris: Librairie scientifique et mèdicale, 93, Boulevard St. Germain. 550 pp. 45 fr. For review see *Mon. sci.*, **10**, 216 (1920). (C. A.)

BOOK REVIEWS

A Text Book of Chemical Engineering. By EDWARD HART, Chemical Publishing Co., Easton, Pa. 1920. Professor Hart's contributions to the acid industry, as well as his teaching experience, cause lively anticipation when a text on chemical engineering appears under his authorship. The present book is a rather small volume, profusely illustrated, as is shown by the list of 200 illustrations in the 206 pages of text. The illustrations are sometimes line drawings, but are frequently half tones taken from trade catalogs. There are chapters on *crushing*, dissolving, *filtration*, *tanks*, evaporation, crystallization, *drying*, distillation, absorption of gases, *mixing* and *kneading*, and *containers*. Although the book is a small one, it deals in an elementary way with subjects which are usually considered as belonging primarily in other divisions of engineering, such as *foundations*, *walls*, *floors*, *roofs*, *boilers*, and *prime movers*.

The treatment throughout is descriptive, with little attempt to develop the theory or its application to the industry. For instance, the chapter on evaporation contains eight illustrations of steam heated cast iron pans taken from one trade catalog. Both the illustrations and the description of multiple effect evaporators are stated to be copied directly from a trade catalog. The chapter on drying is also descriptive, with its material largely taken from trade catalogs and from standardized engineering handbooks. The book gives valuable descriptive information as to types of machinery used in the chemical industry and contains references to original articles and theoretical discussions appearing in literature. ALFRED H. WHITE

ACTIVITIES OF THE SOCIETY

Actions taken by the Board of Trustees

February 7. It was voted that the Editor be allowed $100.00 a month for stenographic work, in addition to the necessary postage, stationery, and office supplies.

February 18. It was voted that the sum of $300.00, more or less as needed, be appropriated for the incidental expenses of the annual meeting.

Meetings of the Board Held During the Annual Meeting at Columbus

February 20. Those present were President R. H. Minton, R. K. Hursh, R. D. Landrum, M. F. Beecher, F. H. Riddle, R. T. Stull, with Charles F. Binns, Secretary, and Norah W. Binns, Assistant Secretary.

The minutes of the Board for the year were read and accepted.

The report to be presented by the Board to the Society was discussed and completed.

It was voted that the Treasurer be instructed to invest, at his discretion, in U. S. Treasury Certificates maturing in six months, and funds above the amount needed for current expenses.

It was voted that Mr. Riddle be requested to write an editorial for the Journal, on a code of ethics between employer and employee in the ceramic industry.

It was voted to recommend to the Rules Committee that the Nominating Committee consist of the two past presidents, and one representative elected by each industrial division and each local section, the Secretary of the Society to be chairman of this committee, without vote. Also that ten members of the Society, at least five of whom shall be Active Members, may form a self-constituted nominating committee and present a ticket of their own.

It was voted that the Board confirm, for 1920 and 1921, the action of August 4, 1919, that 10 per cent of the dues of a member of the Society, belonging to an industrial division, shall be allotted to his division for expenses in connection with the work of the division. In the case of a member who wishes to belong to more than one division, he shall designate his major division and 10% of his dues shall be allotted to that division.

It was voted that, in addition to the membership list arranged alphabetically a geographical list should be printed in the next Year Book.

Ninety-three Associates were elevated to Active Membership by vote of the Board.

February 22. It was voted that the position of Advertising Manager be added to the Committee on Publications, and that Mr. LeRoy W. Allison should be the present incumbent, without vote.

It was voted to contribute fifty dollars ($50.00) to the International Chemical Union toward the publication and distribution of the Annual Tables of Constants, Physical, Chemical, and Technological.

It was voted to appoint a committee of three to investigate and report fully upon the functions of the Society, the possibilities of development in coöperation and research, with a view to the appointment of a full-time Secretary.

February 23. It was voted that Charles F. Binns be re-appointed Secretary and Norah W. Binns, Assistant Secretary, for the years 1921–1922.

The appointment of Dr. E. W. Washburn as Editor of the Journal for the year 1921 was confirmed.

It was voted that all checks and cash received by the Secretary shall be recorded and transmitted direct to the Treasurer for deposit.

It was voted to increase the bond of the Treasurer from $5,000 to $20,000.

It was voted that the Local Sections and Industrial Divisions be requested to furnish a report of any activities to the Board on or before the first of each month, for publication in the Journal.

It was voted that the resolutions on the death of Ernest Mayer be given to the press on request.

The appointment of the Standing Committees by the President was confirmed by the Board.

Associates Elevated to Active Membership by Vote of the Board of Trustees at Columbus, Feb. 20

Agge, Franklin
Albery, D. F.
Allison, LeRoy W.
Ayars, E. E.
Bardush, J. F.
Barnes, T. R.
Booraem, J. Francis
Brockman, E. A.
Brown, Davis
Brown, Leslie
Brown, Wilbur F.
Brush, George S.
Buckner, O. S.
Carter, C. E.
Coulston, E. V.
Crawford, J. L.
Cruikshank, J. W.
Dains, I. F.
Denk, F. J.
Dewitt, Bert G.
Dixon, Henry L.
Douda, Henry W.
Dressler, Conrad
Eskesen, E. V.
Fettke, Charles R.
Foltz, Andrew
Footitt, F. Farnsworth
Forst, D. Parry
Fritz, E. H.
Fuller, Donald H.
Geisinger, E. E.
Geller, Roman F.
Gleason, Marshall W.
Goheen, John P.
Grafton, Charles O.
Grainer, John S.
Guastavino, R., Jr.
Harvey, F. A.
Hepplewhite, J. W.
Hess, Henry W.
Hostetter, J. C.
Jaeger, F. G.
Jones, Chester H.
Keeler, R. B.
Kent, G. G.
Kier, S. M.
Kimes, A. W.
Kingsbury, Percy C.
Krusen, I. A.
Kurtz, John C.
Lambie, J. M.
Lamont, R. A., Jr.
Libman, Earl E.
Manion, L. W.
Metzner, Otto
Moore, H. W.
Morey, George, W.
Mueller, Theodore E.
McKinley, J. M.
Pass, R. H.
Payne, A. R.
Peck, Albert B.
Post, M. P.

Ramsay, J. D.
Rochow, W. F.
Russel, John W.
Scholes, S. R.
Sharp, Chester L.
Shaw, L. I.
Solon, L. V.
Sortwell, H. H.
Stone, Charles H., Jr.
Strong, Thos. L.
Türk, Karl
Tyler, H. B.
Vollkommer, Josef
Vollrath, W. J.
Walton, S. F.
Weil, Edgar H.
Wilkins, Wm. W.
Wilkinson, George D.
Willetts, H. G.
Williams, Warren S.
Zopfi, Albert S.
Zwermann, Theodore

FOREIGN

Andersen, Olaf
Bigot, A.
Gibson, M. F.
Marson, Percival
Mellor, J. W.
Searle, Alfred B.
Shanks, Douglas
Tooth, W. E.

New Members received during February, 1921

Resident Associate

Boudreau, James C., 725 Fulton Bldg., Pittsburgh, Pa., Director of Art Education, Pittsburgh Board of Education.

Brownlee, Wm. L., Toledo, Ohio, Buckeye Clay Pot Company.

Day, O. L., 1513 Kirby Bldg., Cleveland, Ohio, Representative, Harbison-Walker Refractories Company.

Hull, W. A., Bureau of Standards, Washington, D. C., Chief, Optical Glass Division.

Kelly, M. J., 88 Van Dyke St., Brooklyn, N. Y., Vice-President and Manager Brooklyn Fire Brick Works.

Milford, L. R., Solvay Process Company, Syracuse, N. Y., Laboratory Manager.

O'Leary, T. A., 1212 Keenan Bldg., Pittsburgh, Pa., President, T. A. O'Leary Company and Enid Clay Company.

Smith, Charles A., 1150 Oak Street, Columbus, Ohio, Student, Ohio State University.

*__Speir, Oswald__, One Madison Ave., New York City, Executive Secretary, National Terra Cotta Society.

Sutton, Willard J., 423 North Craig St., Pittsburgh, Pa., Graduate Student, University of Pittsburgh.

Weller, Samuel A., North Sixth St., Zanesville, Ohio, Owner, S. A. Weller Art Pottery Company.

Foreign Associate

Bianchedi, Romulo, Calle Junin 1028, Buenos Aires, Argentine, Head of Piccardo y Cia's Glass Works.

Curtis, Algernon Lewin, Westmoor Laboratory, Chatteris, Cambridgeshire, England, Consulting Expert.

Corporation

Dings Magnetic Separator Company, Milwaukee, Wis.

W. S. George Pottery Company, East Palestine, Ohio

Gleason-Tiebout Glass Company, 99 Commercial St. Brooklyn N. Y.

*Deceased.

Minutes of the Third Annual Meeting of the Glass Division, Hotel Deshler, Columbus, Ohio, February 22, 1921

The meeting was called to order at 9.45 A.M. and in the absence of elected officers of the Division Mr. W. M. Clark was elected temporary Chairman. Thirteen papers dealing with various aspects of glass technology were presented and discussed.

Resolutions were passed extending the thanks of the Glass Division to Mr. E. F. Collins and Mr. Ward Harrison for their papers.

A resolution was passed suggesting that at the next meeting there be a special session in the afternoon with the Refractories Division on the subject of glass house refractories and other topics of common interest.

Nominations for officers of the Division were then called for and the following were declared elected:

Chairman, William M. Clark

Vice-Chairman, J. C. Hostetter.

Secretary, E. W. Tillotson.

Councillors, H. S. Dixon, C. O. Grafton.

A vote was then taken on the following amendments to the by-laws which being favorable the by-laws were declared adopted.

Amendment of article VII, Committees—paragraph 1—strike out the word "council" and insert the word "Chairman" so that it shall read: "the chairman of the Division shall from time to time appoint such committees, etc."

Amendment of article VII, Committees—paragraph 2—"At the regular business meeting of the Division nominations may be made of one member for each of the several standing committees of the American Ceramic Society. Such nominees when appointed on a committee of the Society shall serve as chairman of the corresponding divisional committees (the present standing committees are those on Research and Development, Rules, Coöperation, Standards, Sections and Division and Membership. See THIS JOURNAL, November, 1920, page 944).

In conformance with provisions of article VII, paragraph 2, the following nominations for committees were made:

Rules, R. J. Montgomery.

Coöperation, G. W. Morey.

Membership, H. W. Hess.

Standards, A. Silverman.

Sections and Divisions, J. W. Cruikshank.

A letter from Dr. W. E. S. Turner was read extending an invitation for a joint conference in England in 1922. It was voted that the committee be appointed to investigate the cost of the trip and to canvas the membership to determine how many might be interested.

The U. S. Bureau of Standards' Specifications on Limestone, etc., was referred to the Committee on Standards.

It was suggested that the report on specifications for glass house refractories

presented last year be revised and published after having canvassed the Division for an opinion concerning the several paragraphs of the report.

The meeting adjourned at 4.00 P.M. with about fifty members present.

EDWARD TILLOTSON
Secretary of the Glass Division

Minutes of the Organization Meeting of The Art Division

The Ceramic Decorative Processes Division held its first meeting at the twenty-third annual convention of the Society at the Deshler Hotel on Tuesday, February 23. Mr. Wm. W. Wilkins, Chicago, Ill., was made temporary chairman. The following papers were read:

"The Mutual Relation of Art and Technics in Our Industry," Leon V. Solon, Art Director, American Encaustic Tiling Co., New York.

"Relation of the Artist to the Manufacturer," Conrad Dressler, sculptor, potter, inventor of the Dressler Tunnel Kiln, Cleveland, Ohio.

"Some Suggestions for Research in Commercial Ceramic Decorative Processes," Frederick H. Rhead, Director Research, American Encaustic Tiling Co., Zanesville, Ohio.

Following a discussion in regard to the name of this Division it was proposed by Mr. John W. Hasburg and seconded by Mr. Leon V. Solon that the new division be named THE ART DIVISION of the American Ceramic Society. The following officers were elected: Frederick H. Rhead, Zanesville, Ohio, chairman; R. Guy Cowan, Cleveland, Ohio, vice-chairman; Mabel C. Farren, Pittsburgh, Pa., secretary-treasurer; Mr. Leon V. Solon was elected councillor for the architectural, faience, and Terra Cotta treatments. The election of the remaining councillors was postponed until later.

There was some discussion in regard to proposed activities for the coming year. Efforts are to be made to interest manufacturers and those interested in the educational side of the work, studio potters, and the practical workers in the pottery industry. These elements are vitally concerned in the program of THE ART DIVISION.

It was proposed and seconded that a tentative program be made and submitted at an early date for the consideration of the members. The various interests mentioned are to be then approached, and their consideration and suggestions sought.

In conclusion, it was decided that the principal activities for the first year were to be along the direction of including in the membership the various allied activities, and the educational element not yet connected with the Society and also to have an exhibit which will be passed upon by a jury to be named later.

A vote of thanks was given to Miss Margaret Cable for the very interesting exhibit of pottery work which was made under her direction at the University of North Dakota.

FREDERICK H. RHEAD
Temporary Secretary

325

JOURNAL
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A monthly journal devoted to the arts and sciences related to the silicate industries.

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EDITORIAL

NEXT ANNUAL MEETING IN ST. LOUIS, 1922

The Twenty-fourth Anuual Meeting of the American Ceramic Society will be held in St. Louis, February 27 to March 2, 1922. To eastern members this may seem far away, but it should be remembered that to reach Pittsburgh, Philadelphia, and even Columbus, has meant long journeys for the westerners.

St. Louis is growing to greater importance as an industrial city every year. It is one of the largest centers for refractories and heavy clay products, while enameled ware, glass, and terra cotta are abundantly represented. Some of the St. Louis members have said that a week of trips for the inspection of plants would be none too long.

The Hotel Statler will be the headquarters of the Society and its facilities for the comfort of the meetings are unexcelled. Large rooms for divisional meetings, with a choice of ball-rooms and banquet-halls for the general sessions, will be available; while the luxury of the private rooms is too well-known to need description.

It will be noticed that the date is later than is customary. The reason for this is that the month of February is buyers' month in St. Louis, and the city is overcrowded without the additional influx of a national convention. The local men therefore urged that the date be put at the very end of the month, and the decision was made in accordance with this advice.

The attendance at Columbus will be hard to equal, but the A. C. S. has never gone backward. If the eastern members will go less than half way to meet the western ones, and the northerners exactly half way to meet the southerners, we shall have the most representative gathering of a decade.

RESEARCH IN CERAMIC DECORATIVE PROCESSES

Before we can properly undertake any consideration of suggestions for research in connection with the decorative side of ceramics, we must have some general idea of what this subject involves. No research work can be undertaken and carried through to completion (so far as this is possible), unless certain fundamentals are recognized and accepted. These fundamentals may be noted as follows: (1) Adequate resources; (2) A clearly defined purpose; (3) Efficient direction; (4) Experienced practical assistance; (5) A well planned equipment; (6) Educational facilities. We will take these points in order, briefly touching upon essential conditions surrounding each item.

1. **Adequate Resources.**—This condition may be taken in its broadest sense. Financial resources are taken for granted. I refer to all those means, mental and physical, which contribute to the success of an undertaking. Any condition which by its nature interferes with the harmonious progress of a development, and its practical application to the industry is obviously limiting the resources in connection with the activity in question.

Lack of coördination, coöperation, encouragement and appreciation are forces which limit the resources, at least to the same extent as active opposition.

2. **A Clearly Defined Purpose or Program.**—It will be generally conceded that the ideal condition will be that where the manufacturer and research director are in harmony as to the specific purpose of the activity. The manufacturer could present an outline covering his business policy and give a clear exposition in regard to his particular market, present and future possible competition, demand and supply, future possibilities, and present manufacturing conditions. The research man would then formulate a tentative program dealing with improvements for the

present product, and with developments covering some definite space of time mutually agreeable to all concerned. Such conditions as present manufacturing methods, decorative processes, costs of production, percentage losses, standards, personnel, and essential organization, would be fully covered. In order to ensure a comprehensive discussion which would be the basis of a program for future activities, typical examples of the present product of the concern in question together with sample of domestic and foreign competing wares would accompany the report. Included in the report would be opinions from leading dealers covering present and future possibilities.

With the final program determined, working drawings would be executed and actual samples would be made. Proper recognition would be given to those conditions at present in force. A competent director will commence work with as little disturbance as possible, endeavoring to fit into the organization as its exists, while giving it new impetus. But there is a condition covering all types of product that should be insisted upon, and that is, there should be consistent activity in regard to the development of new methods and processes. The same style of decoration worked out in different ways, produces, of course, different results. Even in such standardized activities as the white ware business there are ample possibilities for development. It is simply a question of whether one prefers to work along the lines of the least resistance, or whether one is out for every rational possibility consistent with practical conditions at hand, and the market requirements.

In due time a well organized research department would have a well stocked museum of completely catalogued and classified productions irrespective of the present needs and demands of the market. In the faience, architectural and art ware markets, the possibilities are limitless. In this country we have architects, artists, draughtsmen, sculptors, and decorators of international reputation, and there is no practical reason why their interest should not be aroused, and their services utilized.

3. Efficient Direction.—A progressive manufacturer with a knowledge of the industrial possibilities should have little trouble in finding men capable of formulating and directing a program

having a specific purpose in mind. But it must be remembered that this is not a one man job. It is a work for an organization, with the program so planned that if the head of the department drop out for any reason the activity will go on without interruption. The main idea, the purpose in mind, must be definite. If the manufacturer is a business specialist, and is conscious of his limitations in connection with artistic matters, he can consult a specialist, just as he would do if he was going to law. The specialist in decorative processes, and the artist or designer would advise him, and if he was capable of convincing him of the business possibilities and could plainly demonstrate a practical program, the manufacturer could feel fairly secure in going ahead. The fact of the matter is, the average business man is afraid of the artist. He calls the artist a freak, balks at his so-called temperament, entirely unconscious of the fact that the average business man is the most temperamental man in the world. An inefficient and incapable decorator will often hide his incompetency by posing as a temperamental person, by ignoring essential practical conditions, and often by displaying contempt for the manufacturer because he is not a specialist in applied decoration. As a matter of fact the average manufacturer knows a lot more about art than the average decorator thinks. The efficient art director and director of artistic research must be an efficient executive with a sound knowledge of business principles, and his work, and the work of his department must be subject to the same rational business treatment and scrutiny and the same discipline accorded to the other branches of the activity.

4. **Experienced Practical Assistance.**—It has just been stated that one man could not successfully carry out a work under discussion. A symphony orchestra is not a one man activity. An organization for the manufacture of artistic clay products may be compared to the symphony orchestra. The clayworking organization having a decorative department must have its equivalent of strings, brasses, reeds and percussion instruments. And the mere possession of these instruments is not enough. The performers must know how to play. The assistants must be trained specialists. If they are not, the director must teach them, and obviously, they must be teachable material.

We all love beautiful things, but not everyone is equipped to make them. The artist or decorator is not a superior being. He is a human being like the rest of us. But he does, or he should, possess a mental or intellectual makeup which fits him for this class of work. From a business point of view, he is a very important type essential to the success of some of our most important industries. And the sooner our manufacturers learn to recognize this type, the better it will be for all concerned. The art director, and research man must be particularly interested in this type, and insist that all those who enter the art department are above everything else intensely interested in decorative and creative work. There are many factories where the head of the decorating department is a comparatively uneducated, and certainly uncultured foreman subject to authority from the warehouseman or bookkeeper, and who has not the authority to hire his own help. The wages paid in many instances are so low that no-one really interested in an artistic occupation would consider entering this field. The possibilities must be made attractive enough to draw efficient material. At the best, the building up of an efficient organization is no easy task. It is also an expensive undertaking. In my own work, my personal labor analysis chart shows that over thirty per cent of my time is spent in instruction. But it pays. It would pay if it took sixty per cent of my time. An interested and enthusiastic working force is worth any amount of attention. You can not get results without it.

5. A Well-planned Equipment.—The equipment will obviously vary according to the work to be done. In many of the decorative processes the cost of suitable equipment is practically negligible, in fact so small as to be scarcely figured in the cost of production. But the first essential in a well planned department, and most unfortunately, rarely considered by the manufacturer is that relating to the working conditions under which art work is attempted. I am not exaggerating when I say I have seen studios and decorative work shops that are not fit to be used for stables. The modeling, and mold rooms, about the most interesting parts of the plant are usually dirty and disorderly. There is no excuse for this condition. Adequate

lighting and cleanliness would surely seem to be essentials for any type of work, and I do not think I will be accused of drawing upon my imagination when I state that attractive workshops and studios will be conducive to better work, and increased production.

In regard to necessary equipment for development there is often too much indiscriminate buying. The head of the department may be fond of experimenting and dabbling; first trying out one process and then another. If results are not immediately forthcoming a development is dropped, and something else is attempted. Considerable money and effort have been expended, and so far as the result is concerned, there is merely an additional expense to the department. We all have bright ideas which have a tendency to start us off in some new direction, but impulse is not a very permanent productive force. Ideas should be noted and charted for more mature consideration.

If we have a clearly defined purpose, and are working to a definite program, our equipment has been already carefully planned and specified in the orginal report covering the activity at hand. Any requisition for new equipment should be accompanied by a clear report covering the purpose and the development for which it is intended. And any haphazard or unsystematic attitude towards the planning of the equipment, or the actual work of the development should be discouraged. But a well planned equipment is an essential, and it is my experience that very few manufacturers will be niggardly in this regard following a practical demonstration of its productiveness.

6. **Adequate Educational Facilities.**—This is a big subject, and I have no intention of dealing with it in this paper any further than attempting to outline some of the more essential conditions to be considered.

It is definite that if the manufacturer, the art director, and the director of research in the clay working plants are interested in better artistic products they must take an active interest in the educational side of the work. At the present time the factory is the only place where the student interested in ceramics can obtain a practical training in the various decorative processes used by the potter. I am not referring to the so-called craft or

student work taught in the schools and universities and entirely out of the range of commercial possibility. Yet in these schools there has been for some ten or fifteen years a marked and ever increasing interest in ceramic work. During my twenty years in this country, I have had considerable experience in connection with pottery work as taught in the schools and universities, and I know that there are some hundreds of these institutions who are seriously interested in pottery making and its decoration. This interest should not remain detached. In fact it should be capitalized by the manufacturer. Here is a wealth of material of the highest type for organization and productive purposes open to development if proper encouragement and support is given.

There are many ways of doing this, and the progressive potter does not need assistance in devising ways and means when once he is conscious of the possibilities. It is a lamentable fact that most of our largest pottery centers possess no art or vocational training schools. This condition will of course not always exist, because it is already recognized by forces at present outside the influence of this society and of the pottery manufacturers generally, and it is exemplified by the interest shown in the schools all over the country. But if the potter could be brought to a realization of these possibilities he could utilize these forces to tremendous advantage. As stated previously, this is a big subject and can not be covered within the scope of this present paper. But it is a subject which will have to be dealt with in the near future. Manufacturers and others who have a practical interest in the matter could exchange views, and discuss suggestions offered before some definite program is formulated.

It might be well to state some of the methods employed by the potters of other countries in their efforts to arouse the interest of possible material. In England and on the Continent the manufacturers offer prizes and scholarships to students in the schools who make the best designs, or execute the best work along certain specified lines. These are annual competitions that are followed with great interest. Any factory of average size could well afford to offer such incentive to the students of the local schools, and I believe that if some such idea was ap-

proved by our organization as a body, that a considerable number of the potteries would give prizes and scholarships to students for certain specific works. Such action would result in creating a practical interest, and would be a commencement towards a very healthful coöperation between the industries and the schools. The idea could also be extended to include professionals with some profit. Many English manufacturers obtain some of their most successful designs by offering prizes of sufficient attraction to artists and sculptors of note. I believe also that the American Ceramic Society can be a powerful educational force, especially during our conventions. We meet at least once every year, spend the greater part of our time in discussion of technical papers, but we give little or no attention to the many practical problems of great industrial interest to the manufacturer and the public. I would like to see a convention where the program included the general public. The various manufacturers would submit examples of their products, the schools examples of student work. As far as possible each exhibit would be accompanied with a detailed classification of process. Papers on this day would be of such character as to appeal to the general public, and the educational authorities could be approached in regard to the possibility of a session for the benefit of the local schools. The local papers would be interested and the resulting publicity would be good for our organization. We can not expect to realize the full possibilities for the development of the industry by keeping aloof from that public which is very definitely interested in our activities. Such movements as I suggest will be brought about whether we like it or not. When school children are dabbling in pottery, when independent organizations such as the Apprentice Schools of design, and the Art Alliance are active in this direction, this is evidence of interest which could profitably be coördinated with the interest of the manufacturer.

I am the last man in this Society to belittle the importance of the purely technical man, and when I say that he is simply a cog in a clay working organization, I am only one of an increasing number of pottery men who realize that if the American Ceramic Society is to establish its proper influence in the clay working industries the members as a body must be rationally sympathetic

to those closely allied activities which in turn must be educated to an intelligent understanding of the tremendously important work being done by present day industrial clayworking organizations.

In conclusion, I offer some suggestions for research and general investigation along the lines mentioned. The suggestions are grouped according to the fundamental conditions outlined at the beginning of this paper.

Group One: A Clearly Defined Purpose.—Contributions from manufacturers, decorators, modelers, practical process men, pottery instructors, museum authorities and the layman. Papers and discussions relating to general program for art productions.

Group Two: Adequate Resources.—Papers and discussions defining and outlining specific resources for the production of various wares. A manufacturer may be interested in the production of new types, but he is not familiar with costs and conditions involved. The educational authority may be interested in pottery instruction while lacking knowledge of essential conditions. The ceramist interested in educational work is the man to submit an outline of these conditions.

Group Three: Efficient Direction.—Papers dealing with the organization of art departments, accompanied with discussions of various possible systems of recording and charting experimental work.

Group Four: Experienced Practical Assistance.—Papers outlining specialized activities and giving necessary physical and mental qualifications for each particular field.

Group Five: Adequate Equipment.—Papers outlining complete equipments with costs covering the various processes.

Group Six: Adequate Educational Facilities.—Papers dealing with ceramic instruction, covering various possible systems of apprenticeship, courses of instruction in both the factory or schools, and rational coöperation and coördination between the factories and schools.

This class of investigation would cover plans for the encouragement of pottery work, schemes for exhibitions, and for the

coöperation between other art and architectural organizations. When important art or architectural exhibitions are held, manufacturers, practical men and educators could plan to attend, if not in a body, at least individually, reporting such activities to the head of that division most interested.

Above all, we should not confine our activities to mere talk. Those of us who are interested in progressive development in any industry are usually busy men, a class who prefer to do things rather than talk about them. We are quite prepared to take part in necessary discussions if the discussions produce tangible results. We can not get results without action. Not action from one man, or one particular group of men, but by the properly coördinated efforts of all those forces which contribute to the success of any big undertaking.

The Art Division is, I think, willing to do its share in regard to those activities which meet with the approval of the Society as a body, and it will in due time submit to the trustees a definite program covering such action for the remainder of the present year. It invites suggestions and criticisms concerning points discussed at this meeting, and any other idea which comes to the attention of those interested.

The work will be helped tremendously if it will be possible at future conventions to have a meeting of the heads of the various divisions. The decorative men need the assistance of the technicians, and both these groups can not work without the practical men, and last, but not least, the manufacturer is an official whose attendance is absolutely necessary if we are to get very far with our program.

Frederick H. Rhead

American Encaustic Tiling Company
Zanesville, Ohio

ELECTRICALLY HEATED GLASS ANNEALING LEHR[1]

By E. F. Collins

ABSTRACT

Time-temperature data relating to relaxation of stresses.—Existing time-temp. data covering the relaxation of stresses in annealing of glass has been assembled. Range, control, and distribution of temp. are important factors in annealing. The annealing time was reduced from 5 to 2.3 hours when temp. var. was reduced from 10° to 2.5° C, in the case of one glass whose annealing temp. was 476°.

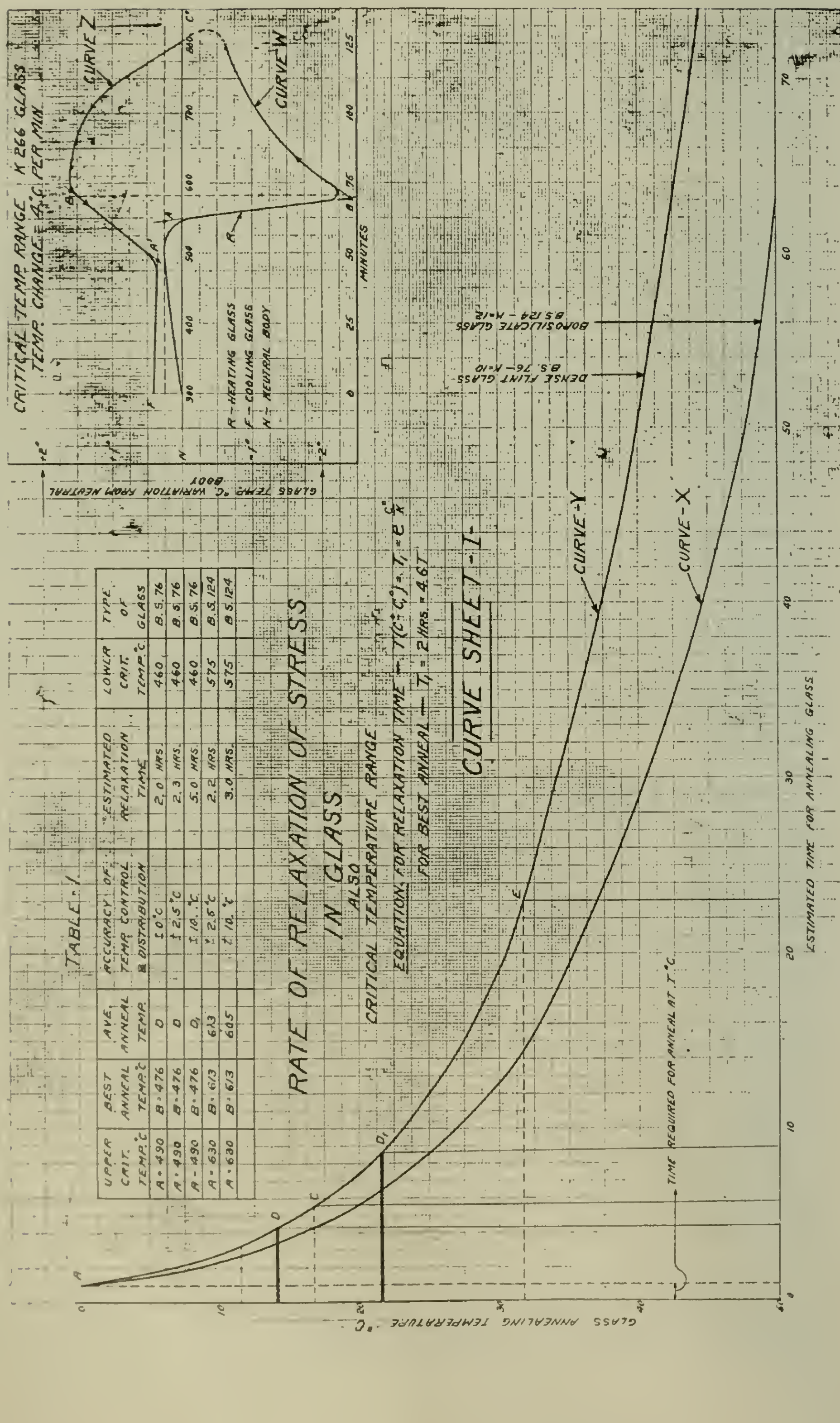
Electric heat secures perfect anneal in shortened time.—Electric heat with its automatic control holds temp. within +0.6 per cent in ranges required for annealing, as shown by tests, even when the temp. changes 23° per hour and when the annealing treatment (as for optical glass) covers a month in time.

Vertical Lehr superior to horizontal type.—Electrically heated lehrs of horizontal and vertical types are discussed. The vertical lehr offers many apparent advantages and a higher thermal efficiency. A particular lehr of 500–600 lbs. ware capacity per hour, shows efficiencies in ratio of 6 to 10 in favor of electric lehr of vertical type. Tests made on an electrically heated vertical lehr annealing high grade ware showed a reduction in cost of manufactured part of 20 per cent, or more than 75 times total cost of electric power consumed.

In suggesting the use of electric heat for glass annealing lehrs, the writer of this paper is not unaware of the indefiniteness and scarcity of published data covering the conditions necessary for satisfactory and uniform anneal of a specific type of glass. Data presented in this paper is in nowise original; the writer has drawn freely from published reports.[2] He recognizes that this process is one of the most delicate in the manufacture of glass; and that the actual annealing procedure for one type of glass varies widely from that of another. On the other hand whether glasses differ in composition, and whether they be used for industrial and domestic purposes or optical and scientific work, the problems involved in the heat treatment or annealing procedure necessary to meet service requirements and specifica-

[1] Received February 21, 1921.

[2] Bureau of Standards' paper No. **358**, also Rosenhain, Williamson and Roberts, Tool and Valasek, and W. M. Clark.



UPPER CRIT. TEMP. °C	BEST ANNEAL TEMP. °C	AVE. ANNEAL TEMP.	ACCURACY OF TEMP. CONTROL & DISTRIBUTION	ESTIMATED RELAXATION TIME	LOWER CRIT. TEMP. °C	TYPE OF GLASS
A - 490	B - 476	D	± 0 °C	2.0 HRS.	460	B.S. 76
A - 490	B - 476	D	± 2.5 °C	2.3 HRS.	460	B.S. 76
A - 490	B - 476	D_1	± 10 °C	5.0 HRS.	460	B.S. 76
A - 630	B - 613	613	± 2.5 °C	2.2 HRS.	575	B.S. 124
A - 630	B - 613	605	± 10 °C	3.0 HRS.	575	B.S. 124

Fig. 1.

tions are in general very much the same, whether the annealed product be judged by the sensitive polariscope, or "strain viewer," or by simple tests such as pouring hot water into fruit jars, "bump" and "drop" tests, or the testing of bottles by a sharp rap from a hickory stick in the hands of an inspector educated in its use.

Ordinary glass ware is considered to be sufficiently annealed when stresses as great as 5 per cent of the breaking stresses are present. However where double refraction must be eliminated, or where change of form due to slow relaxation of stresses is objectionable, as in optical instruments or thermometers, further

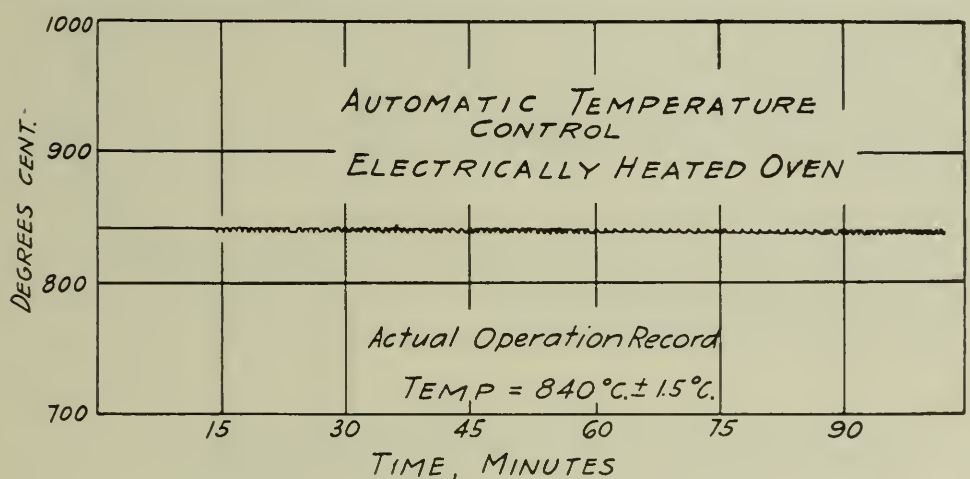
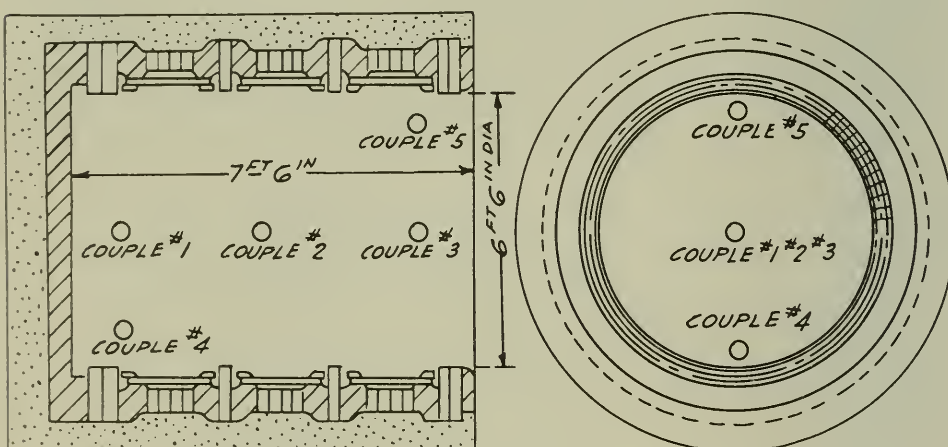


FIG. 2.

reduction of stresses are necessary. A piece of fine annealed glass, 8 inches in diameter suitable for a telescope lens, gave only one-third the retardation of a normally annealed plate.

In all glass annealing, it is of vital importance that the temperature of the glass mass should be uniform in the annealing range. Temperature gradients in the mass of homogeneous glass under treatment, are solely responsible for the setting up of strains. These gradients may result from too great speed of cooling, as well as from a non-uniform and unsymmetrical heat distribution. Hence the importance of heat control with respect to time and also proper heat distribution in the annealing lehr through which the ware is passing. Likewise where glass is treated in the box type oven, it is extremely important that the heat distribution of the oven be correct and that the heating

equipment lend itself to the exact following of the time temperature cycle desired, what ever that may be, *i. e.*, annealing cycles covering a few hours and those covering a month should be equally accurately followed no matter what the temperatures and the rates of change required throughout; and preferably such temperature time control should be automatic and should correspond to a predetermined cycle.



TIME	THERMOCOUPLES-TEMP °C.					AVER TEMP	PER CENT DEVIATION FROM AVERAGE		RATE OF CHANGE
	1	2	3	4	5		ABOVE	BELOW	DEG. PER. HR
11^{30}	25	25	25	25	25	25	0	0	
3^{30}	527	537	532	530	545	534	2.07	1.31	127°c
7^{30}	670	679	671	666	669	669	1.5	.45	34
11^{30}	777	783	776	766	780	776	1.0	1.3	27
3^{30}	858	864	857	849	864	860	.46	1.3	21
7^{30}	860	865	862	862	863	862	.35	.23	0
11^{30}	928	934	930	930	928	930	.43	.21	17
3^{30}	933	932	927	925	927	929	.64	.43	0
4^{30}	950	950	952	952	955	952	.31	.21	23

FIG. 3.—Test data of heat uniformity of electric furnace.

The importance of exact temperature control at least from the economic point of view, is illustrated by Curve Sheet I (Fig. 1), which in general shows the change in annealing time with the temperature of anneal. Suppose the point D, for a flint glass is the best temperature point to anneal in two hours time for ordinary purposes, say where stresses are reduced to $^1/_{10}$ the breaking value. Assume an automatic temperature control

of 476° ± 2.50°C, then the actual time for anneal at the average temperature of 476°C is 2.3 hours as against 2 hours at 476°C with perfect control. Again assume a less close control, *e. g.*, one whose variation is ±10°C. Then the average anneal would occur at D_1 or about 468°C and a total relaxation time for safety corresponding to temperature E, or about 5 hours. Here due to the difference in sensitiveness of heat controls we have doubled the length of time for the anneal and undoubtedly for the greater part have an inferior glass product.

An automatic temperature control within ±2.5°C is available if electrically heated annealing lehrs of proper design are used. The variation of ±10°C is usually a fair measure of non-uniform or unsymmetrical temperature distribution and control met with in the fuel fired lehr operating at such temperatures as 475°C.

As an illustration of what may be accomplished in temperature control in electrically heated ovens, attention is called to the time temperature curve in figure 2. This is a curve record of an actual performance which holds temperature constant within 0.3 of one per cent.

An example of temperature distribution is given in figure 3 and its accompanying table. It will be noted that for a rising temperature of 125° per hour, only one point varies from the mean temperature by 2.07 per cent. With 35° change per hour, the variation from mean temperature is 1.5 per cent maximum while with the temperature changing at the rate of 17° per hour, the maximum deviation from mean is only 0.43 per cent, and at constant temperature, *viz.*, at 860° maximum variation is 0.35 per cent and at 930° the variation is 0.64 per cent in an oven 6 ft. 6 inches diameter and 7 ft. 6 inches deep. Such control and distribution of heat as the above, should, it would seem, meet the most exacting requirements of any and all types of glass annealing, including the fine annealing of large lenses for telescope work.

Curve Sheet III, figure 4, shows the time temperature cycle required in the "fine anneal" of a crown glass lens for telescopic purposes. Such a process is best carried on in the box type of lehr, figure 5 in which the lens is placed and subjected to a tem-

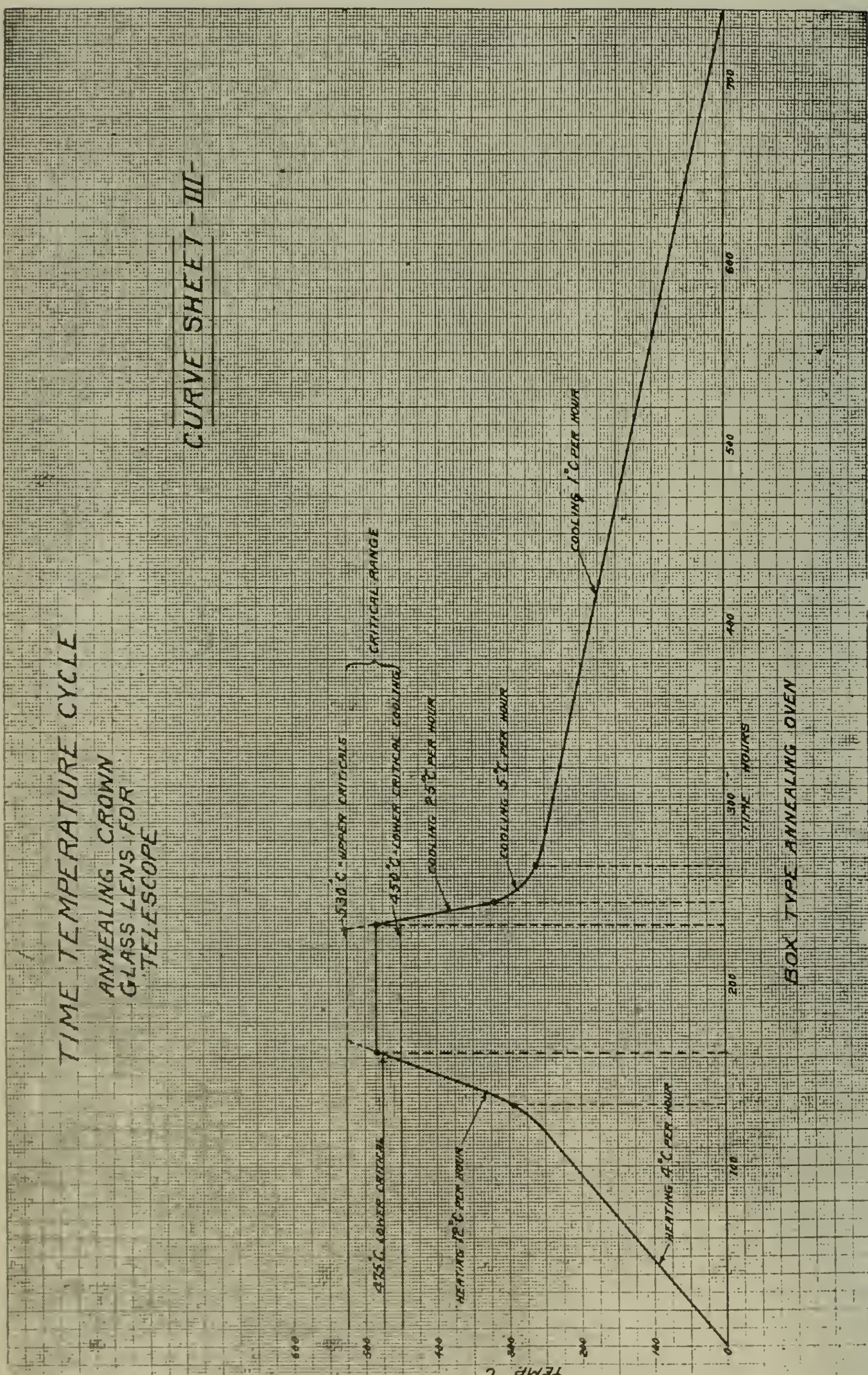

TIME TEMPERATURE CYCLE
ANNEALING CROWN
GLASS LENS FOR
TELESCOPE
CURVE SHEET -III-
530°C = UPPER CRITICALS
CRITICAL RANGE
450°C = LOWER CRITICAL COOLING
475°C LOWER CRITICAL
COOLING 2.5°C PER HOUR
COOLING 5°C PER HOUR
COOLING 1°C PER HOUR
HEATING 12°C PER HOUR
HEATING 4°C PER HOUR
TIME HOURS
BOX TYPE ANNEALING OVEN
TEMP °C
GENERAL ELECTRIC COMPANY SCHENECTADY NY. U.S.A (METRIC DIVISIONS)

FIG. 4.

perature cycle as shown. Automatic control is available together with electric heat whereby this particular cycle or any similar one may be followed and repeated exactly whenever desired. The control instrument is operated by a time keeping motor supplemented by a simple cam arranged to give different rates of heating or cooling according to a predetermined characteristic such as shown on Curve Sheet III, figure 4. Certain tests for fine anneal with this type of apparatus have been made and our reports thus far seem to indicate that results may be obtained that have not been realized in any other method of annealing. Results are not the product of chance but may be duplicated repeatedly due to well nigh perfect distribution coupled with an absolutely positive and dependable automatic control of the temperature time cycle.[1]

Curve Sheet II, figure 6, shows the characteristics suited to the annealing of a large part of the glass ware in use for domestic and industrial purposes. These curves are built up from data on Curve Sheet I, which carries in general data regarding critical points and relaxation time which must be observed in arranging for successful anneal. Here it is assumed that the stresses are reduced to at least $^1/_{10}$ of those which will produce rupture of the glass ware. The two curves in figure 1 show how the relaxation[2] time varies with different glass compositions.

Returning now to Curve Sheet II, figure 6, the two heavy curves represent the annealing cycles which glass receives in a conveyor type lehr when the temperature control is $\pm 5°$ (Curve X), and when the temperature control is $\pm 15°$ (Curve Y), respectively, figure 7, shows the ordinary commercial lehr, with conveyor, and fitted with electric heat, and which when equipped with automatic control will readily give temperature cycle (Curve X), Curve Sheet II, required for a particular glass; this annealing period totals three hours and 20 minutes. This time includes heating up from 400°C to 590°C, the necessary relaxation time 5 minutes and safe cooling time three hours from 585°C to 375°C

[1] See the New York Tribune, Sept. 15, 1920, for news bulletin of the American Chemical Society in which successful operation of electric furnace to the annealing of telescope discs by Geo. W. Morey, is announced.

[2] For table showing critical range for several specific glasses, see Bureau of Standards, *Technical Paper* No. 358.

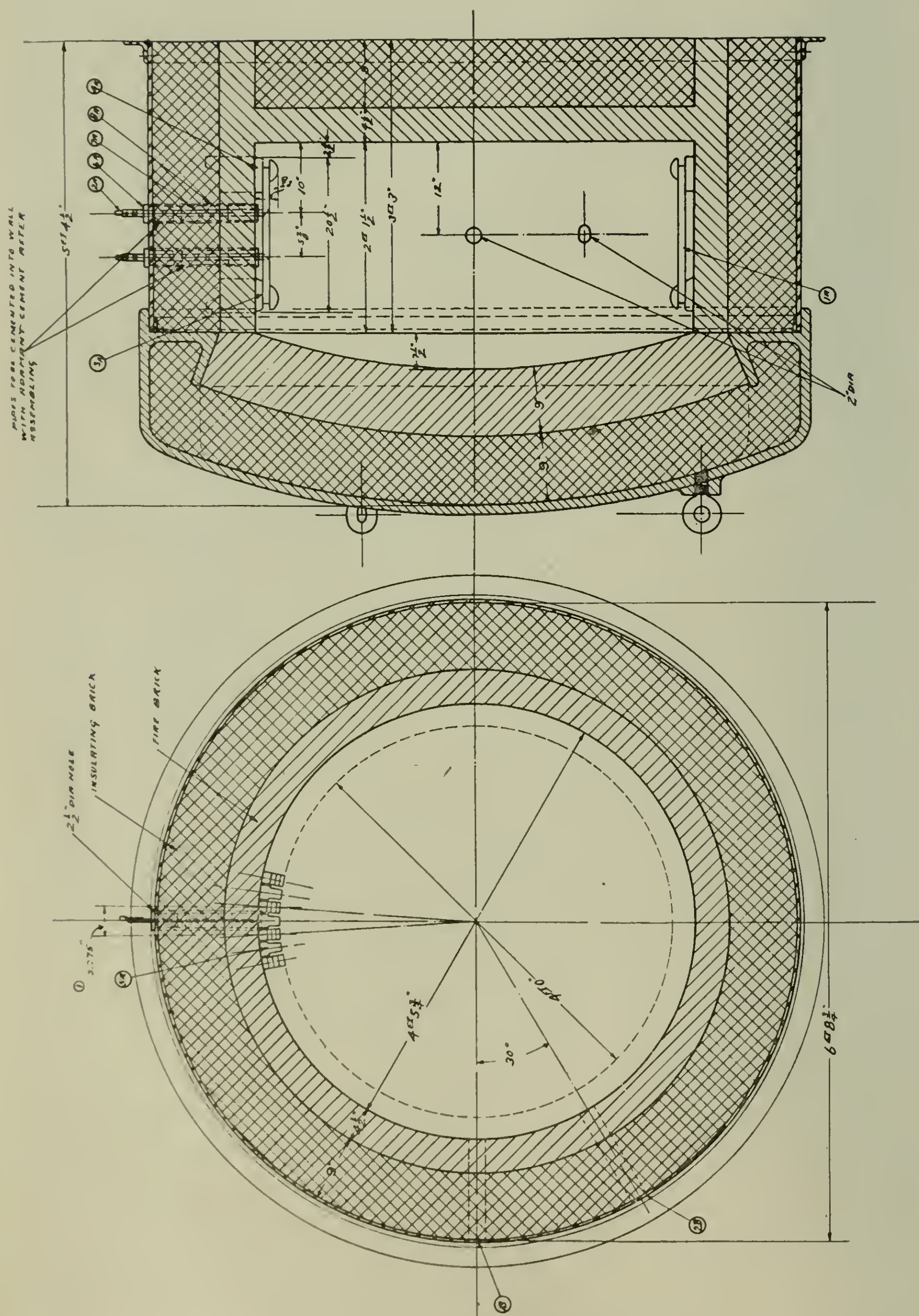

PIPES TO BE CEMENTED INTO WALL WITH ADAMANT CEMENT AFTER ASSEMBLING
FIRE BRICK
INSULATING BRICK
2½" DIA HOLE
2" DIA
30°

Fig. 5.

where it may be exposed to the air. Were the lehr, figure 7, of the usual fuel fired type, the glass would necessarily be subjected to a cycle comparable with Curve Y, due to non-uniformity of heat distribution and wider range of control. The output would be less uniform and dependable than glass subjected to the much shorter cycle, Curve X. In other words, the complete cycle length embracing the same temperature stages is 8 hours and 15 minutes for Curve Y, as against 3 hours 20 minutes for Curve X; a reduction of about 60 per cent in length of anneal in favor of the electrically heated lehr. In other words, the electric lehr should handle easily twice the ware of the fuel heated lehr when introducing and removing the ware from the lehr at the same temperatures, *viz.*, 400°C and 375°C.

While positive tests are not yet available to prove the correctness of the above reasoning, indications are that they will be realized in a lehr designed to take full value of the advantages inherent in the electric heat and its perfect control.

From the standpoint of the electric heating engineer, a glass lehr design, shown in figure 8 embodies many advantages for rapid, uniform and economic annealing of most commercial glass. Among its possible advantages are the following: (1) high thermal economy, (2) heat distribution easily secured, (3) small floor space required, (4) may be located near fabricator and receive ware at higher temperature, (5) reduction in labor, (6) no opportunity for ware to absorb products of combustion, (7) low temperature gradient, (8) heat control, —2.5°C may be secured automatically, (9) annealing time less than one-half that required by present day fuel fired lehr, (10) practical elimination of rejects, distortion, and breakage due to heat treatment, (11) no sulphuring of the ware occurs and the product has a bright polished surface requiring no subsequent cleansing or washing, (12) the ware is sterile and absolutely clean as all microbes are destroyed by heat so that for prescription ware, this feature has importance as medicinals can be filled in and sealed immediately after leaving the lehr.

Specific conditions would no doubt call for a modified design over that shown in figure 8, but it is presented here to call attention to some advantages which ought to be realized with this general type in commercial annealing.

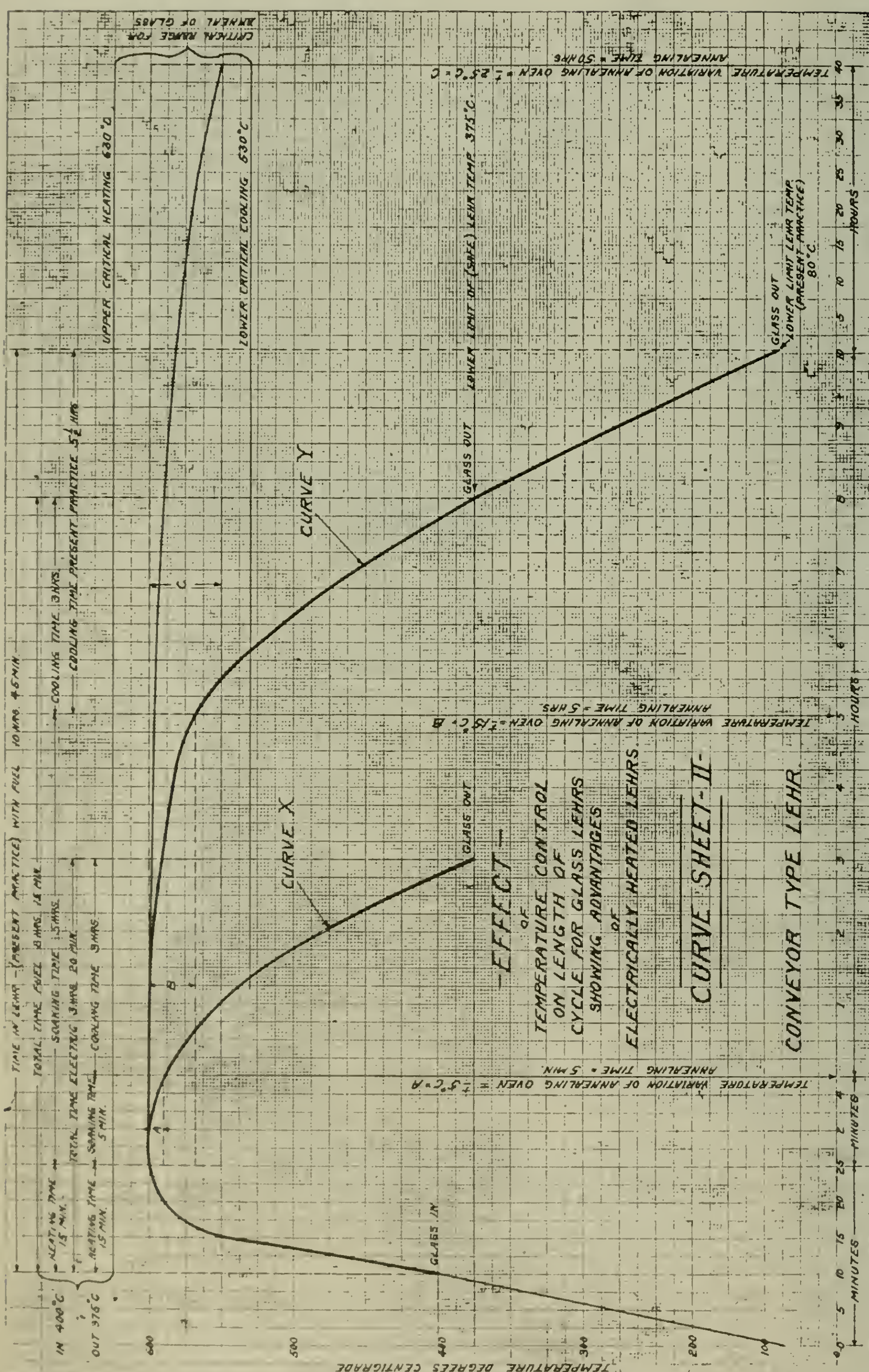
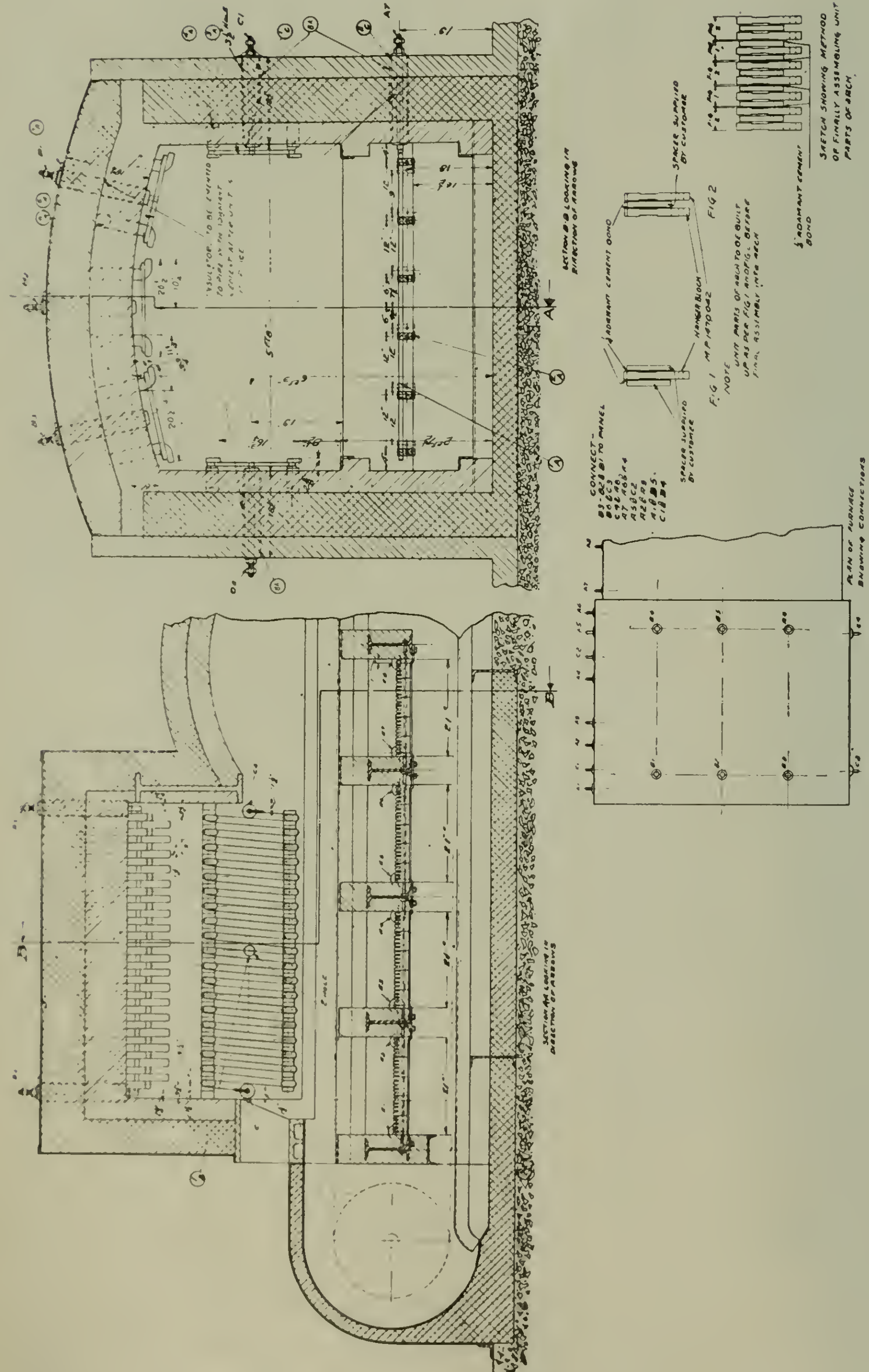

-EFFECT- OF TEMPERATURE CONTROL ON LENGTH OF CYCLE FOR GLASS LEHRS SHOWING ADVANTAGES OF ELECTRICALLY HEATED LEHRS
CURVE SHEET-II-
CONVEYOR TYPE LEHR
CURVE X
CURVE Y
GLASS IN
GLASS OUT
GLASS OUT
GLASS OUT
UPPER CRITICAL HEATING 630°C
LOWER CRITICAL COOLING 530°C
LOWER LIMIT OF (SAFE) LEHR TEMP. 375°C
TEMPERATURE DEGREES CENTIGRADE
MINUTES
HOURS

Fig. 6.

Exact operating costs for electrically heated lehrs are not yet available, but several estimates made for commercial work are being realized and in some installations, there are large savings in favor of electric heating, when overall costs, quality, increased production, and elimination of rejects are taken into account. The heavy conveyor type of lehr of present day usage, with its very great heat absorption or capacity and low thermal efficiency, which disqualifies it for best results of electrification, gives an efficiency when equipped with electric heating of six lbs. of glass ware per kw. hour. The estimate for the vertical type described above, electrically heated, is 10 lbs. of glass per kw. hour. These figures are based on ware entering lehr at about 900°F and being raised to temperature not above 1200°F. The horizontal lehr used for above calculations occupied a floor space of 70 ft. by 10 ft. and height of 10 ft. with a glass capacity of 600 lbs. per hour. The vertical lehr would occupy a floor space of 18 ft. by 21 ft. and its rated capacity would be 500 lbs. of ware per hour. The connected electric load of the vertical lehr would be 60 kw. as against 125 kw. for the horizontal type.

An electrically heated vertical lehr and which replaced a gas heated lehr has now been running for several months on a high grade glass ware and reliable overall factory costs have been made up for the annealed part. These factory costs show a decrease per unit annealed of 20 per cent or a cost of but 80 per cent of the former cost when annealed in gas-heated lehr. The saving was about 75 times the total cost of power for heating lehr.

In conclusion, while the writer appreciates that the logical development of annealing by electric heat, and certain assumptions in this paper may be at variance with, if not contradictory to, certain phases of established practice, he himself is thoroughly convinced that the soundness of the proposition has been fairly well demonstrated by the careful experiments reported by the Bureau of Standards, the Geophysical Laboratory, and the University of Sheffield, England, not to mention those conducted in our own laboratories, and supported by some satisfactory practical demonstrations with production lehrs. The writer urges that serious consideration be given the electric lehr by



SUBJECT TO CHANGE NOT FOR CONSTRUCTION UNLESS SPECIALLY APPROVED

FIG. 7.—Assembly of ribbon resistor furnace.

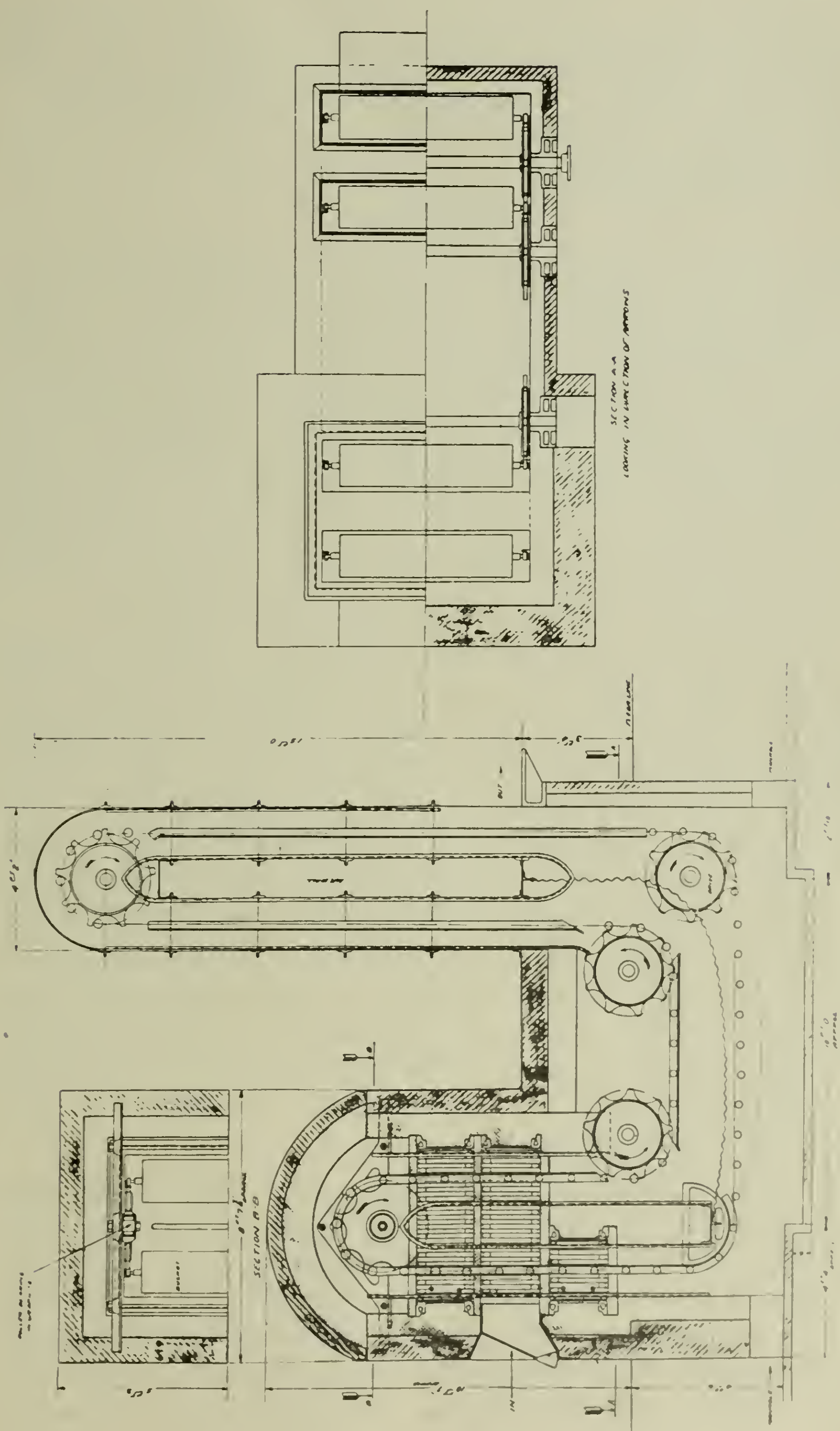


FIG. 8.

glass manufacturers, with the full confidence that its installation and use will demonstrate the claims of superiority and result in the standardization of such equipment for annealing glass.

Industrial Heating Department
General Electric Company
Schenectady, N. Y.

Discussion

L. H. Adams: To one who is interested in glass-annealing it is very gratifying to observe the progress made by Mr. Collins in developing electric annealing furnaces. The electric heated lehr is without doubt the ideal equipment for the purpose. A temperature constant within 2° or 3°C and uniform over the whole interior to within the same amount; the ease with which the temperature can be automatically controlled so as to follow any desirable time-temperature curve; low operating costs; uniform quality of annealing—all these indicate the superiority of the electric furnace as compared with the gas-fired equipment.

In working out actual annealing schedules, however, it would seem that Mr. Collins has not taken advantage of the most recent data on the annealing of glass. The most advantageous annealing schedule can not be determined solely from observations of the "critical ranges" for the various kinds of glass. It is necessary to have a complete set of data on the annealing-times for various temperatures. Furthermore, it can be shown that the best annealing schedule requires that the annealing-time be equal to the cooling time; that the glass be cooled at an increasing rate; that thick pieces be annealed at lower temperatures than thin pieces; and that the total time required is proportional to the square of the thickness. The time-temperatures given by Mr Collins show the glass to be cooled at a *decreasing* rate even at the higher temperatures.

The "best" annealing temperatures for "dense flint" glass (Bur. Stds. No. 76) is given as 476°. This is probably too high, since any kind of flint glass of reasonable thickness should not be annealed at a temperature higher than 430° (cf. *J. Franklin Inst.* 190, 852 (1920)). The schedule for a crown glass telescope lens as shown in "Curve Sheet III" indicates that a total of 700 hours would be required for the annealing process. Now the

largest lens blank ever made in this country is six inches thick, and a piece of glass of this thickness should not require more than 300 hours for a very complete annealing. Similarly the schedule according to which commercial glass requires 3 hours is probably too long. The total time of the annealing process for thin glass ware could be reduced to little more than one hour.

Author's Closure.—I am gratified that Mr. Adams points out that the most recent data on the annealing of glass defines further, important conditions that work toward shortening the annealing cycle. This means that when the electric lehr is in the hands of the glass manufacturing expert, who can apply the most advantageous anneal schedule in every case, the limit of its accomplishment will be much in advance of the claims made in my paper.

SOME DATA ON THE COMPOSITION OF ARSENIC ENAMELS FOR COPPER[1]

By B. T. Swefly

ABSTRACT

Methods of application are by usual wet slushing, and sieving powdered enamel on to clean copper sheets and fusing to a smooth coat. Where slush-coat is necessary it is advisable to use an enamel free from lead and arsenic as a ground. In this work the dry method is used exclusively. In the formulae given, increase of SiO_2 increases fracturing or shivering, increase of B_2O_3 above 0.2 equiv. in presence of 0.1 equiv. As_2O_3 causes enamels to come mat. Increasing KNaO at expense of PbO decreases opacity, improves fit and gloss, but makes enamel more soluble. The following limits in composition are recommended: 0.3 to 0.7 KNaO, 1.3 to 1.8 SiO_2, 0.7 to 3 PbO, 0.0 to 0.2 B_2O_3, 0.05 to 0.15 As_2O_3.

The data on the type of enamel presented below were secured by the writer in an investigation of arsenic enamels for copper. No attempt was made to cover the field of all possible compositions nor the allowable limits of different materials, the purpose in mind being the gathering of sufficient data to produce a suitable and workable enamel for the particular job under consideration. This work was of such a nature as to require an enamel very similar to a watch dial enamel in appearance and application, but it was necessary to apply it in a much heavier coat than is the usual practice on dial work.

There are two methods of application of enamels of this type in use commercially—one is the usual method of wet grinding and applying as a slip—the other of sieving the dry powdered enamel on to the clean copper sheet and firing in the usual manner. In this work the latter method was used exclusively as it was best adapted to the work in hand and eliminated the necessity of adding clay and setting up agents to the enamel slip. When it is desired to enamel both sides of a shape or one with vertical surfaces, the wet method is, of course, indispensable. In such cases it has been the writer's experience that the best results

[1] Received March 19, 1921.

are secured by applying a ground coat free from lead before putting on the lead-bearing arsenic enamel, due to the ready attack of the copper by lead enamels when applied in thin coats, resulting in a disagreeable green color in spots unless the pieces are very evenly dipped.

The formula of a ground coat with which good results were secured on thin copper sheet is given below:

GROUND COAT FOR COPPER

$$\left.\begin{array}{l} 0.15\ K_2O \\ .55\ Na_2O \\ .20\ CaO \\ .10\ BaO \end{array}\right\} 0.15\ Al_2O_3 \left\{\begin{array}{l} 1.8\ SiO_2 \\ 0.4\ B_2O_3 \end{array}\right.$$

Materials	Equiv.	Batch Wts.
Feldspar	0.15	83.5
Soda nitrate	.10	17.0
Soda Ash	.45	47.7
Whiting	.20	20.0
Barium Carbonate	.10	19.7
Boric Acid	.40	49.6
Flint	.90	54.0

Milled with 5% Clay and 10% Tin Oxide.

A search of the available literature yielded but little information on the type of enamel in mind. Minneman[1] reports some very good work on Cloisonne enamels using a clear leadglass, while Randau's "Enamels and Enameling" gives some data on the manufacture of watch and clock dials with tin enamels, but only the former's work proved to be of any value in this study.

That arsenic is a good pacifier for glass and enamel is, of course, well known, and for the production of densely opaque and very white enamels it is almost indispensable. Due to the poisonous nature of its compounds and its ease of volatilization, however, it is but little used except for those classes of work where its use is necessary to secure a certain quality of whiteness and opacity in the finished enamel. Preliminary experiments led the writer to believe that an arsenic enamel was best fitted to the work in mind, and the following study was planned in order to secure the necessary data from which to develop an enamel

[1] *Trans. A. C. S.*, **13**, 514.

of the desired opacity, color, etc. The materials used were of ordinary ceramic grade, and as they were of about the same degree of purity as would be obtainable for manufacturing purposes, no analyses, etc., were made on them. The enamels were weighed out in gram formula weights and checked by weighing the total batch. They were then thoroughly mixed by sieving and smelted in a small crucible gas furnace until a thread of glass drawn from the metal was free from knots, quenched in cold water, dried, and ground in a small porcelain jar mill to just, pass fifty mesh. The copper trials were No. 16 stock 2″ square, and were cleaned by dipping in dilute nitric acid, washed in clean water and quickly dried. The powdered enamel was then sieved onto the clean copper in a coat heavy enough to secure the desired thickness of enamel and fired in a small electric furnace. No data on firing will be included since any enamel firing operation depends so largely on weight of metal, number of pieces in heat, etc., that it is of little value at best, but in general it may be said the enamels all matured at from 850°C to 900°C.

The trials were examined for opacity, luster, fit, and their firing behavior observed, *i. e.*, whether or not they flowed out readily to form a smooth uniform coating on the copper. The fit was judged by the tendency of the enamel to "fracture" in cooling.

The first series studied was with the addition of silica to a base enamel, which was essentially a mean of the hard and soft fluxes recommended by Minneman,[1] to which 0.1 equiv. As_2O_3 and 0.15 equiv. B_2O_3 had been added. In this series, the RO, As_2O_3 and B_2O_3 were maintained constant and the SiO_2 increased in steps of 0.1 equiv. as shown.

Series I

Molecular Formula

Enamel	K_2O	Na_2O	PbO	As_2O_3	B_2O_3	SiO_2
A	0.40	0.10	0.50	0.10	0.15	1.8
B	.40	.10	.50	.10	.15	1.9
C	.40	.10	.50	.10	.15	2.0
D	.40	.10	.50	.10	.15	2.1
E	.40	.10	.50	.10	.15	2.2

[1] *Loc. cit.*

BATCH WEIGHTS

Enamel	Pearl Ash	Soda Nitrate	Red Lead	Arsenious Oxide	Boric Acid	Flint
A	55.2	17.0	114	19.8	18.6	108
B	55.2	17.0	114	19.8	18.6	114
C	55.2	17.0	114	19.8	18.6	120
D	55.2	17.0	114	19.8	18.6	126
E	55.2	17.0	114	19.8	18.6	132

Every enamel in this series fractured, becoming worse with each increase silica. All enamels flowed well and had good luster and opacity.

Conclusions on Series I.—Increase of silica caused an increase in the tendency of the enamels to fracture but had no other bad effects except to raise the maturing temperature.

Series II

In Series II, Enamel "A" of Series I was chosen as the base enamel and the boric acid omitted. The RO, arsenic and silica were maintained constant and boric acid increased in steps of 0.1 equiv. as shown.

MOLECULAR FORMULA

Enamel	K_2O	Na_2O	PbO	As_2O_3	B_2O_3	SiO_2
A	0.40	0.10	0.50	0.10	0.0	1.8
B	.40	.10	.50	.10	.1	1.8
C	.40	.10	.50	.10	.2	1.8
D	.40	.10	.50	.10	.3	1.8
E	.40	.10	.50	.10	.4	1.8

BATCH WEIGHTS

Enamel	Pearl Ash	Soda Nitrate	Red Lead	Arsenious Oxide	Boric Acid	Flint
A	55.2	17.0	114	19.8	0	108
B	55.2	17.0	114	19.8	12.4	108
C	55.2	17.0	114	19.8	24.8	108
D	55.2	17.0	114	19.8	37.2	108
E	55.2	17.0	114	19.8	49.6	108

Every enamel in this series flows well.

A. Fractured when too thick—good opacity and luster.
B. Fractured—good luster and opacity.
C. Fractured—good luster and opacity.

D. Fracturing less pronounced—enamel comes mat—good opacity.

E. No fracturing—very mat and very opaque.

Conclusions on Series II.—Increase of boric acid above 0.2 equivalents caused the enamels to become mat. The mat finish of these enamels does not develop appreciably, if the enamel is drawn as soon as it is fused to glossy surface, but seems to develop if heated long enough for the enamel to flow out and fill an enclosure as in Cloisonne work. It has been suggested that this mat texture may be due to volatilization of some constituent from the enamel under prolonged heating, leaving a sort of vesicular structure which gives a mat surface. Whether this finish is due to volatilization or to crystallization, it develops only when boric acid and arsenic are both present in sufficient amount, and does not appear in these enamels if either of these constituents is omitted. Microscopic examination of these enamels would undoubtedly show the cause of this mat finish and prove of no little interest to the users of this type of enamel.

Fracturing in this series seemed to decrease with increase of B_2O_3, which is the converse of the results secured in Series I with increase of SiO_2. Since it is usual to assume that increase of either B_2O_3 or SiO_2 in a glass results in a decrease in its coefficient of expansion, the results of the two series seem rather contradictory. Since, however, variations in the thickness of coat applied has a decided influence on the development of defects in fit, it is the writer's opinion this series should be carefully checked by further investigation before definite conclusions are drawn.

Series III

In Series III, it was planned to use as the base enamel, a formula that would fracture in order to find what effect variation in the RO would have upon this defect, and Enamel I E was chosen as the base. Since it was desired to increase and decrease PbO in the same formula in steps of 0.1 equiv. it was necessary to make the base enamel the middle of the series. Enamel III D is, therefore, the base enamel of Series III, and as mentioned, is Enamel E of Series I, the As_2O_3 and SiO_2 being constant.

Molecular Formula

Enamel	K_2O	Na_2O	PbO	As_2O_3	B_2O_3	SiO_2
A	0.10	0.10	0.80	0.10	0.15	2.2
B	.20	.10	.70	.10	.15	2.2
C	.30	.10	.60	.10	.15	2.2
D	.40	.10	.50	.10	.15	2.2
E	.50	.10	.40	.10	.15	2.2
F	.60	.10	.30	.10	.15	2.2
G	.70	.10	.20	.10	.15	2.2

Batch Weights

Enamel	Pearl Ash	Soda Nitrate	Red Lead	Arsenious Oxide	Boric Acid	Flint
A	13.8	17.0	182.4	19.8	18.6	132
B	27.6	17.0	159.6	19.8	18.6	132
C	41.4	17.0	136.8	19.8	18.6	132
D	55.2	17.0	114.0	19.8	18.6	132
E	69.0	17.0	91.2	19.8	18.6	132
F	82.8	17.0	68.4	19.8	18.6	132
G	96.6	17.0	45.6	19.8	18.6	132

Results

A. Rather mat—does not flow well and will not mature under 950°C. No fracturing—very opaque—attacks copper vigorously.

B. Good luster and opacity—does not flow well—not much softer than A—fractures rather badly—attack of copper not so pronounced.

C. Good luster and opacity—flows well—does not attack copper appreciably—fractures badly.

D. See Enamel I E.

E. Nice smooth enamel—flows well—good luster and opacity—good fit.

F. Good luster—poor opacity—flows well—good fit—rather soluble in water.

G. Same as F but no opacity—matures to a clear glass—quite soluble in water.

Conclusions on Series III.—Increase of K_2O at expense of PbO—decreased fracturing and attack of copper made enamel flow and mature at a lower temperature—decreased opacity and improved luster. The fact that Enamel A did not fracture may be due to the fact that it seemed impossible to properly mature this enamel without its becoming so stained with copper taken up from the trial piece as to turn it an unsightly green. It was, therefore, probably not entirely fused, which might account for its irregular behavior

General Conclusions

The results of this investigation seem to indicate that with an arsenic content of 0.1 equivalent As_2O_3 in an enamel of this type applied by the dry method, the following relations hold ture.

1. Increase of silica with RO, arsenic and boric acid constant, increases tendency of enamels to fracture, increases refractoriness, does not affect opacity except by dilution and does not affect luster.

2. Increase of boric acid above 0.2 equivalents, with RO, arsenic and silica constant, causes enamels to become mat. Increase of boric acid decreases tendency toward fracturing, which is the converse of results obtained in Series I with increase of silica.

3. Increase of K_2O at expense of PbO with arsenic, boric acid and silica constant, causes enamels to flow better, mature at a lower temperature, increases solubility, decreases tendency to fracture, and those enamels containing more than six-tenths equivalents KNaO mature to a clear glass.

4. High lead enamels are very opaque but do not flow well and show an excessive attack of the copper.

From the data at hand, the writer feels justified in recommending the following limits in composition for enamels of this type.

MOLECULAR FORMULA LIMITS

$$\left.\begin{array}{l} 0.3\text{–}0.6\ \mathrm{KNaO} \\ .7\text{–}\ .4\ \mathrm{PbO} \end{array}\right\} \quad \left\{\begin{array}{l} 1.3\text{–}1.8\ \mathrm{SiO_2} \\ 0\ \ \text{–}0.2\ \mathrm{B_2O_3} \\ 0.05\text{–}0.15\ \mathrm{As_2O_3} \end{array}\right.$$

As stated at the beginning of this paper, no claims for the completeness of this work are made. The data are presented in the hope that it may prove of value in this field of the enamel industry and stimulate sufficient interest in others to continue the work here begun.

The writer takes this occasion to express his appreciation of the kindly assistance of Mr. Staley and Mr. Danielson of the Bureau of Standards in checking the data given above and their advice as to its presentation.

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NICKEL OXIDE IN GLAZES[1]

By J. D. Whitmer

ABSTRACT

Colors produced from NiO.—The literature on this subject published in the Transactions of the Society is briefly reviewed.

Effects of variations of RO in cone 6 glazes on colors from nickel oxide.—*Red* colors are produced when ZnO and BaO are used in certain proportions. *Blues* and *purples* of varied shades and hues are developed with varied combinations of ZnO, CaO and BaO. *Grays* are possible in presence of CaO and MgO.

The transactions of our Society contain a few references to the colors produced by nickel oxide in glazes. These references are scattered through a number of volumes. To gather up the data and present it together with any new developments which might be obtained is the purpose of this paper. Furthermore, it was desired to determine, if possible, the influence exerted by each RO oxide on colors produced by oxide of nickel.

The conditions outlined make necessary, therefore, some overlapping with work previously done. This repetition, however, serves a useful purpose in emphasizing and strengthening conclusions already drawn.

Geijsbeck[2] states that Le Chatielier and Chaupuy in Paris reported the following colors obtained from nickel oxide in oxidizing fire: violet, blue, green, yellow, red and brown. Many of these colors are familiar to most of us. Some no doubt are unusual. Browns and yellows are the usual colors in lead glazes and under ordinary conditions. Blues and greens, more or less familiar colors, were once attributed to traces of cobalt in with the oxide of nickel.

Pence, however, in his study,[3] "Colors Produced by Nickel Oxide in Ceramic Mixtures Containing Zinc," demonstrates that nickel oxide of the highest purity gives colors changing from

[1] Received March 10, 1921.

[2] *Trans. A. C. S.*, **6**, 195.

[3] *Trans. A. C. S.*, **14**, p. 144.

brown through purple, reddish purple to blue as ZnO replaces BaO and CaO, and further that the blues thus obtained can not be duplicated by the use of cobalt oxide.

Nothing more red than the reddish tone of purple obtained by Pence had ever come under my observation. Hence the possibility of producing a red color from NiO was quite alluring. In paper presented[1] last year it was demonstrated that gray colors are produced by NiO in the presence of MgO.

Experimental

Inasmuch as this work is a continuation and enlargement of that previously reported, the base glaze used was the same and much of the present investigation was based on the results obtained at that time. The work was so planned that as each RO oxide replaced another the effect on the color produced by NiO could be noted.

The following base glaze was used:

$$\left.\begin{array}{r} 0.25\ K_2O \\ .45\ BaO \\ .30\ CaO \end{array}\right\} 0.35\ Al_2O_3 — 2.00\ SiO_2$$

The amount of NiO used was kept at 0.025 equivalent except in Series X; it was a straight addition to each glaze.

Series 1—ZnO *vs.* **BaO.**—This is a continuation of a series in the previous paper[2] in which ZnO replaces BaO. In the present instance the ZnO replaces BaO by 0.05 equivalent until the latter is eliminated from the formula.

Series 2—CaO *vs.* **K_2O.**—With no BaO in the RO, CaO replaces K_2O by 0.05 equivalent until the latter is eliminated from the formula. It will be noted here that the final 0.05 K_2O was replaced by 0.05 ZnO making the last glaze of the series have an RO of 0.5 ZnO, 0.5 CaO.

Series 3—ZnO *vs.* **CaO.**—We start this series with the original RO formula, 0.25 K_2O, 0.30 CaO, 0.45 BaO. ZnO replaces CaO by 0.05 equivalent until CaO is eliminated from the formula. We may compare this with Series 1 wherein ZnO replaces BaO.

[1] *J. Am. Ceram. Soc.*, **1920**, 663.

[2] *Loc. cit.*

Series 4—ZnO *vs.* **K_2O.**—Wishing to parallel the high CaO-ZnO glaze of Series 2, the K_2O in glaze 6 of Series 3 was replaced by ZnO in increments of 0.05 equivalent until the content of 0.5 ZnO is reached. The remaining 0.05 K_2O is then replaced by 0.05 BaO and we have glaze 5 with an RO content of 0.5 BaO, 0.5 ZnO.

In order to determine the different effects produced when MgO replaced each of the other RO oxides, the four following series were constructed:

Series 5.—With an RO consisting of 0.15 K_2O, 0.40 ZnO, 0.45 BaO as in glaze 2, series 4, MgO replaces BaO by 0.05 equivalents up to and including 0.20 MgO. ZnO and K_2O do not change.

Series 6.—With the same RO as in Series 5, MgO replaces ZnO in like manner, the BaO and K_2O remaining unchanged.

Series 7.—Starting with an RO consisting of 0.15 K_2O, 0.45 CaO, 0.40 ZnO, MgO replaces CaO by 0.05 equivalents until a content of 0.20 MgO is reached. ZnO and K_2O remain unchanged.

Series 8.—Using the same RO as in series 7, MgO replaces ZnO in like manner, the K_2O and CaO remaining constant.

When the results of these eight series were noted and it was found that a red color was obtained in glaze 2, series 4, the two following series were added to indicate what effect, if any, variations in the Al_2O_3 and NiO content might have on the red color.

Series 9.—Starting with glaze 2, series 4, Al_2O_3 was reduced by 0.05 equivalents to 0.10 equivalent, keeping the oxygen ratio constant at 1:2.

Series 10.—With the same glaze, the nickel oxide was varied from 0.025 to 0.10 equivalent.

Materials.—Formulae and batch weights of all the glazes are found in table 1. The materials used in this investigation were taken from regular factory stock and include the following: Eureka Feldspar, English Cliffstone Whiting, Red Seal Oxide of Zinc, Oxide of Nickel, Granville Flint, Cornwall Stone, Precipitated Barium Carbonate, Calcined Magnesite, Calcined N. C. Kaolin.

TABLE 1

Series 1

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

Glaze No.	Formulae K_2O	CaO	BaO	ZnO	Batch Weights Feldspar	Stone	Whiting	Barium Carb.	Oxide Zinc	Calc. Clay	Flint	Nickel Oxide
1	0.25	0.30	0.20	0.25	83.4	84.3	30.0	39.4	20.25	14.43	...	1.87
2	.25	.30	.15	.30	83.4	84.3	30.0	29.55	24.30	14.43	...	1.87
3	.25	.30	.10	.35	83.4	84.3	30.0	19.70	28.35	14.43	...	1.87
4	.25	.30	.05	.40	83.4	84.3	30.0	9.85	32.40	14.43	...	1.87
5	.25	.30	.00	.45	83.4	84.3	30.0	...	36.45	14.43	...	1.87

Series 2

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

Glaze No.	K_2O	CaO	BaO	ZnO	Feldspar	Stone	Whiting	Barium Carb.	Oxide Zinc	Calc. Clay	Flint	Nickel Oxide
1	0.20	0.35	....	0.45	83.4	42.15	35.0	...	36.45	29.41	19.74	1.87
2	.15	.40	....	.45	55.6	42.15	40.0	...	36.45	40.51	31.74	1.87
3	.10	.45	....	.45	55.6	...	45.0	...	36.45	55.50	54.00	1.87
4	.05	.50	....	.45	27.8	...	50.0	...	36.45	66.60	66.00	1.87
5	.00	.50	....	.50	...	...	50.0	...	40.50	77.70	78.00	1.87

Series 3

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

Glaze No.	K_2O	CaO	BaO	ZnO	Feldspar	Stone	Whiting	Barium Carb.	Oxide Zinc	Calc. Clay	Flint	Nickel Oxide
1	0.25	0.25	0.45	0.05	83.4	84.3	25.0	88.65	4.05	14.43	...	1.87
2	.25	.20	.45	.10	83.4	84.3	20.0	88.65	8.10	14.43	...	1.87
3	.25	.15	.45	.15	83.4	84.3	15.0	88.65	12.15	14.43	...	1.87
4	.25	.10	.45	.20	83.4	84.3	10.0	88.65	16.20	14.43	...	1.87
5	.25	.05	.45	.25	83.4	84.3	5.0	88.65	20.25	14.43	...	1.87
6	.25	.00	.45	.30	83.4	84.3	...	88.65	24.30	14.43	...	1.87

Series 4

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

Glaze No.	K_2O	CaO	BaO	ZnO	Feldspar	Stone	Whiting	Barium Carb.	Oxide Zinc	Calc. Clay	Flint	Nickel Oxide
1	0.20	....	0.45	0.35	83.40	42.15	...	88.65	28.35	29.41	19.74	1.87
2	.15	....	.45	.40	55.60	42.15	...	88.65	32.40	40.51	31.74	1.87
3	.10	....	.45	.45	55.60	...	...	88.65	36.45	55.50	54.00	1.87
4	.05	....	.45	.50	27.80	...	...	88.65	40.50	66.60	66.00	1.87
5	.00	....	.50	.50	...	...	...	98.50	40.50	77.70	78.00	1.87

Series 5

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

Glaze No.	Formulae K_2O	BaO	ZnO	MgO	Batch Weights Feldspar	Stone	Barium Carb.	Oxide Zinc.	Calc. Magnesite	Calc. Clay	Flint	Nickel Oxide
1	0.15	0.45	0.40	0.00	55.60	42.15	88.65	32.40	...	40.51	31.74	1.87
2	.15	.40	.40	.05	55.60	42.15	78.80	32.40	2.015	40.51	31.74	1.87
3	.15	.35	.40	.10	55.60	42.15	68.95	32.40	4.030	40.51	31.74	1.87
4	.15	.30	.40	.15	55.60	42.15	59.10	32.40	6.045	40.51	31.74	1.87
5	.15	.25	.40	.20	55.60	42.15	49.25	32.40	8.060	40.51	31.74	1.87

Series 6

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

1	0.15	0.45	0.35	0.05	55.60	42.15	88.65	28.35	2.015	40.51	31.74	1.87
2	.15	.45	.30	.10	55.60	42.15	88.65	24.30	4.030	40.51	31.74	1.87
3	.15	.45	.25	.15	55.60	42.15	88.65	20.25	6.045	40.51	31.74	1.87
4	.15	.45	.20	.20	55.60	42.15	88.65	16.20	8.060	40.51	31.74	1.87

Series 7

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

		CaO					Whiting					
1	0.15	0.40	0.45	0.00	55.6	42.15	40.0	36.45	...	40.51	31.74	1.87
2	.15	.35	.45	.05	55.6	42.15	35.0	36.45	2.015	40.51	31.74	1.87
3	.15	.30	.45	.10	55.6	42.15	30.0	36.45	4.030	40.51	31.74	1.87
4	.15	.25	.45	.15	55.6	42.15	25.0	36.45	6.045	40.51	31.74	1.87
5	.15	.20	.45	.20	55.6	42.15	20.0	36.45	8.060	40.51	31.74	1.87

Series 8

Common to all glazes: 0.35 Al_2O_3; 2.00 SiO_2; 0.025 NiO

			CaO				Whiting					
1	0.15	0.40	0.40	0.05	55.6	42.15	40.0	32.40	2.015	40.51	31.74	1.87
2	.15	.40	.35	.10	55.6	42.15	40.0	28.35	4.030	40.51	31.74	1.87
3	.15	.40	.30	.15	55.6	42.15	40.0	24.30	6.045	40.51	31.74	1.87
4	.15	.40	.25	.20	55.6	42.15	40.0	20.25	8.06	40.51	31.74	1.87

Series 9

Common to all glazes: 0.45 BaO; 0.025 NiO

	Formulae				Batch Weights						
Glaze No.	K_2O	ZnO	Al_2O_3	SiO_2	Feldspar	Stone	Barium Carb.	Oxide Zinc	Calc. Clay	Flint	Nickel Oxide
1	0.15	0.40	0.35	2.00	55.6	42.15	88.65	32.40	40.51	31.74	1.87
2	.15	.40	.30	1.90	55.6	42.15	88.65	32.40	29.41	31.74	1.87
3	.15	.40	.25	1.75	55.6	42.15	88.65	32.40	18.32	28.74	1.87
4	.15	.40	.20	1.60	55.6	42.15	88.65	32.40	7.22	25.74	1.87
5	.15	.40	.15	1.45	83.4	...	88.65	32.40	...	33.00	1.87
6	.10	.45	.10	1.30	55.6	...	88.65	36.45	...	42.00	1.87

Series 10

Common to all glazes: 0.45 BaO; 2.00 SiO_2

	Formulae				Batch Weights						
Glaze No.	K_2O	ZnO	Al_2O_3	NiO	Feldspar	Stone	Barium Carb.	Oxide Zinc	Calc. Clay	Flint	Nickel Oxide
1	0.15	0.40	0.35	0.025	55.6	42.15	88.65	32.4	40.51	31.74	1.87
2	.15	.40	.35	.050	55.6	42.15	88.65	32.4	40.51	31.74	3.74
3	.15	.40	.35	.075	55.6	42.15	88.65	32.4	40.51	31.74	5.61
4	.15	.40	.35	.100	55.6	42.15	88.65	32.4	40.51	31.74	7.48

The glazes were weighed up separately, ground in small trial mills and applied, by dipping, to thin porous wall tile bisque ($1^1/_2'' \times 1^1/_2'' \times 0^1/_8''$).

All glazes except those of series 9 and 10 were fired at the same time in a commercial down-draft kiln. The fuel used was natural gas. Cones placed in each sagger of glazed tile indicated a temperature corresponding to cone 6.

The majority of the glazes were matured at this temperature although some of those high in MgO were somewhat immature. The glazes of series 9 and 10 were fired at another time but the cones indicated a heat treatment very similar to that of the first burn.

Results

Series 1.—Glaze 1, reddish purple; glaze 2, more blue than glaze 1; glaze 3, mingled blue and tan, the blue apparently consisting of crystals on a tan background; glaze 4, goes bright, blue where thickest, yellowish color on edges of tile where thinnest; glaze 5, greenish matt, tending to blue crystalline where thickest.

The odd behavior of glaze 4 which went bright was attributed to a mistake in weighing the glaze, but a new batch, carefully checked, was made up and upon firing gave very similar results. Evidently some peculiar action, similar to the formation of a eutectic, occurs with 0.05 BaO.

These results indicate that an increase of ZnO at the expense of BaO gives colors tending toward blues and greens and away from purple tones. This contradicts Minton's statement[1] in his discussion of my paper last year that "the effect of BaO produces blue green with NiO" and confirms my previous observations.

Series 2.—Glaze 1, crystalline blue, similar to glaze 5, series 1, from which it differs only by 0.05 CaO replacing 0.05 K_2O. The crystals are small but the effect is very pleasing; glaze 2, purplish blue of slightly mottled nature; glaze 3, similar to glaze 2; glazes 4 and 5, more of grey blue color. The increase of CaO at expense of the K_2O seems to intensify the resulting blue color.

[1] *J. Am. Ceram. Soc.*, **1920**, 669.

High whiting and high zinc together gives light greyish blues. The surface of glaze 5 which contains only CaO and ZnO in the RO is of an unpleasant greasy nature.

Series 3.—Glaze 1, brown; glaze 2, purplish blue; glaze 3, purplish blue; glaze 4, purple; glaze 5, about like glaze 4; glaze 6, reddish purple.

The results of this series confirm Pence's statement that purples and blues arc developed as ZnO increases at the expense of BaO and CaO. If we compare the results of this series with the results obtained in series 1 last year wherein ZnO was used to replace BaO, we see that BaO and CaO produce much the same colors when used in connection with ZnO.

Series 4.—Glazes 1 and 2, these glazes develop decided reds which have a more or less purplish tone; glaze 3, light blue, similar to glaze 4, series 2; glaze 4, similar to glaze 3; glaze 5, more reddish than glazes 3 and 4.

In this series, with high ZnO and BaO, the reddish tone frequently observed has developed into a red of a somewhat purplish tone. This red develops where the glaze is dipped rather heavy and seems to be a segregation on the surface of the blue. Where the glaze is dipped light, the blue color predominates with only here and there a fleck of red on the surface. This red color seems to be developed within the following narrow limits of RO composition:

0.15	0.20	K_2O
.35	.40	ZnO
.45	.40	BaO

Later experiments tend to confirm this action and indicate that a variation of only about 0.05 equivalent in any one of these three oxides is permissible.

Series 5.—Glaze 1, red; glaze 2, blue; glaze 3, blue; glaze 4, lighter blue; glaze 5, lighter blue, nearer to turquoise.

The replacement of BaO with MgO in presence of ZnO gives blues, but lightens the tone. No purple blues are noticeable. The glazes are hardened somewhat as the MgO increases.

Series 6.—Glaze 1, blue; glaze 2, light grey blue; glaze 3, faded lilac; glaze 4, more grey than glaze 3.

The MgO replacing ZnO in presence of BaO hardens the glaze more than in the previous series. Furthermore, greater changes in color occur. This is equivalent to saying that ZnO has a more powerful effect on the color produced by NiO than has CaO and BaO.

Series 7.—Glaze 1, medium dark blue; glaze 2, bright glaze, yellow brown with blue segregations (Compare glaze 4, series 1); glaze 3, light green semi-matt; glaze 4, lighter in color than glaze 3, semi-matt; glaze 5, still lighter than glaze 4.

In glaze 2 this series, with a content of 0.05 MgO, we observe the same phenomenon as in glaze 4, series 1, which contains 0.05 BaO. The glazes in this series are hardened when MgO replaces CaO and the colors are lightened and tend toward grey greens.

Series 8.—Glaze 1, light blue; glaze 2, mingled grey and blue; glaze 3, good grey; glaze 4, grey, slightly browner than glaze 3.

In this series, wherein MgO replaces ZnO in presence of CaO, nice greys are developed. Last year it was shown that greys were developed when MgO replaced BaO with no ZnO in the formula. This leads to the conclusion that greys are not developed when the ZnO is present in too large quantities and the tendency of ZnO is to produce greys of bluish tones.

Series 9.—All glazes of this series are reds of the same purplish tone as glazes 1 and 2, series 4. The reduction of Al_2O_3 does not destroy the red color. It does, however, soften the glaze and produces better surfaces.

Series 10.—The red color changes from purplish to brownish as the NiO is increased.

Discussion of Results

A study of these results brings out some interesting facts. In the first place, a very interesting red color has been produced using NiO as the coloring agent. This color seems to be confined to a very narrow range of glaze composition so far as the RO is concerned. A content of not less than 0.35 BaO and 0.35 ZnO seems necessary, but both must not be this low at the same time.

This red color seems to be a crystalline segregation on the surface of a blue color, the blue always predominating when the glaze is dipped light. Within the limits studied the Al_2O_3 content may vary at will. The content of NiO influences the shades of red produced.

In the second place, more data on the development of grey colors is noted. It appears that CaO is necessary to the formula in producing greys; that the ZnO should not exceed 0.30 equivalent; that the MgO should approximate 0.15 equivalent; that BaO is not necessary in the formula, but that its presence is not detrimental. BaO may replace a part of the CaO as was shown in the paper of last year.

Conclusions

We conclude, therefore, that the following statements are justified as a result of this study:

(1) The dominant tendency of ZnO is to produce blue colors with NiO, as already reported by Pence.

(2) ZnO is not necessary in the production of greys with NiO but may be present if it does not exceed 0.30 equivalent.

(3) BaO with CaO and K_2O gives browns, with ZnO, purples, reddish purples and reds when the proper proportions are used.

(4) BaO is not necessary to produce greys but may be present in the formula partly replacing CaO.

(5) CaO with ZnO produces blues and must be present with MgO to produce greys.

(6) MgO tends to produce greyish tints when used with other oxides. To produce neutral greys it should be used with CaO or a combination of CaO and BaO. Bluish tones of grey are obtained when ZnO is present.

(7) The coloring influence of K_2O is slight but its presence promotes maturity and good surfaces.

American Encaustic Tiling Company
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NOTE ON THE EFFECTS OF FIRING TEMPERATURES ON THE STRENGTH OF FIRE-CLAY AND STONE-WARE BODIES[1]

By H. G. Schurecht

ABSTRACT

The cross breaking strengths, porosities and shrinkages of fire-clay and stoneware bodies were determined after firing to different temperatures. It was found that with one exception, *maximum strength was developed by firing to cone 8, even when porosity and shrinkage data showed the bodies to be over or underfired at this temperature.* The cause of weakening above cone 8 may be due to the formation of sillimanite. Bodies which develop maximum shrinkage and minimum porosity at cone 8 have a greater ratio of fired strength to dry strength when fired to cone 8, than those which are under or overfired at cone 8.

Considerable work has been done on the physical properties of clays fired at different temperatures as evidenced by the fact that a very large per cent of the Society's publications falls under this general head. Much still remains to be done and as time advances, more data are being added to our present knowledge. Since the durability of certain clay wares is closely related to their physical properties such as modulus of rupture, compression, tensile strength and torsion strengths, resistance to impact, modulus of elasticity, etc., a closer study of these properties and of the factors governing them is important.

In studying stoneware and fire-clays, it was observed that the firing temperatures were in general more effective in producing maximum cross-breaking strength than was the degree of vitrification. For most clays of the fire-clay type, maximum strength was developed by firing to cone 8, regardless of the degree of vitrification.

The porosity and shrinkage data showed that many clays and mixtures developed maximum shrinkage and minimum porosity at temperatures below cone 8, but did not develop maximum

[1] Received March 10, 1921. Published by permission of the Director, U. S. Bureau of Mines.

Figure 1

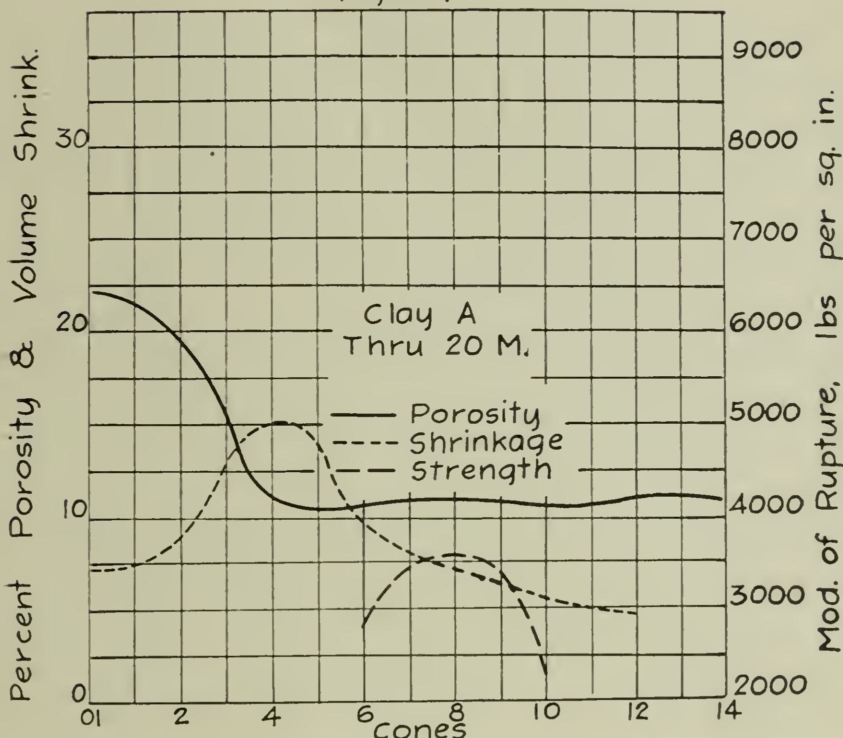


Figure 2

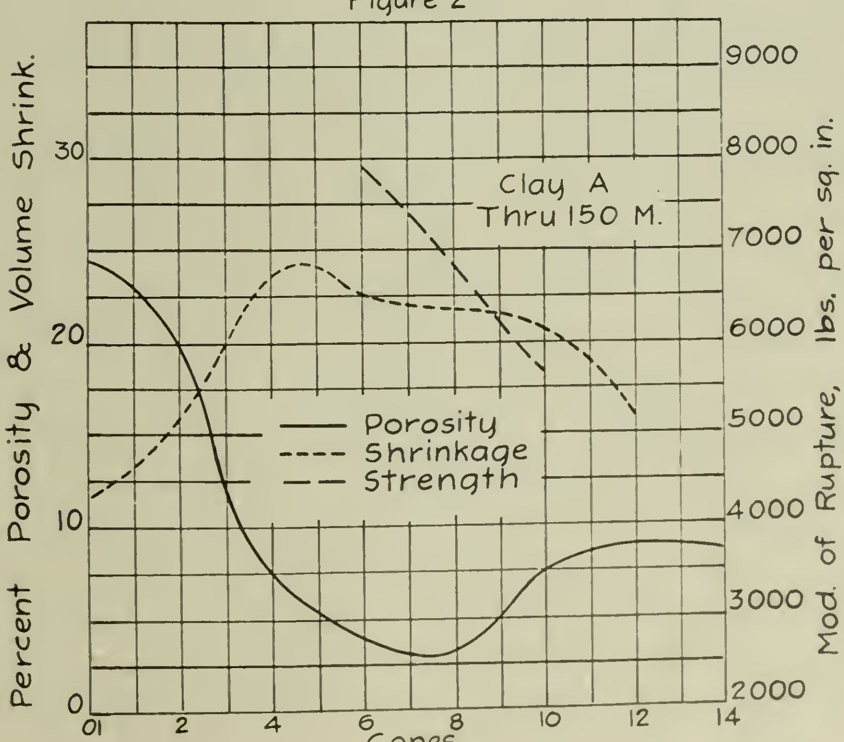


Figure 3.

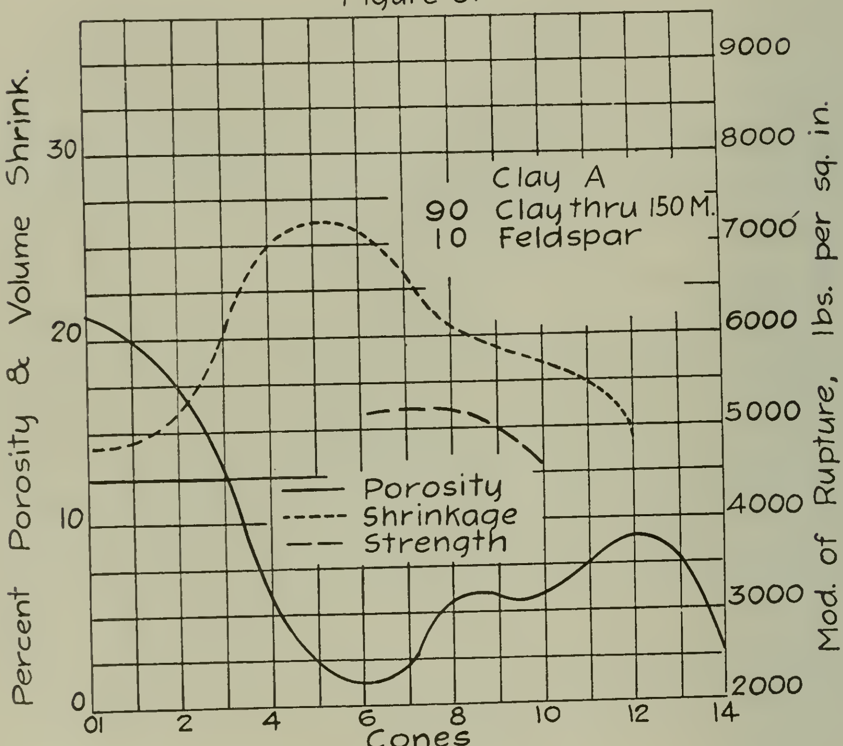


Figure 4.

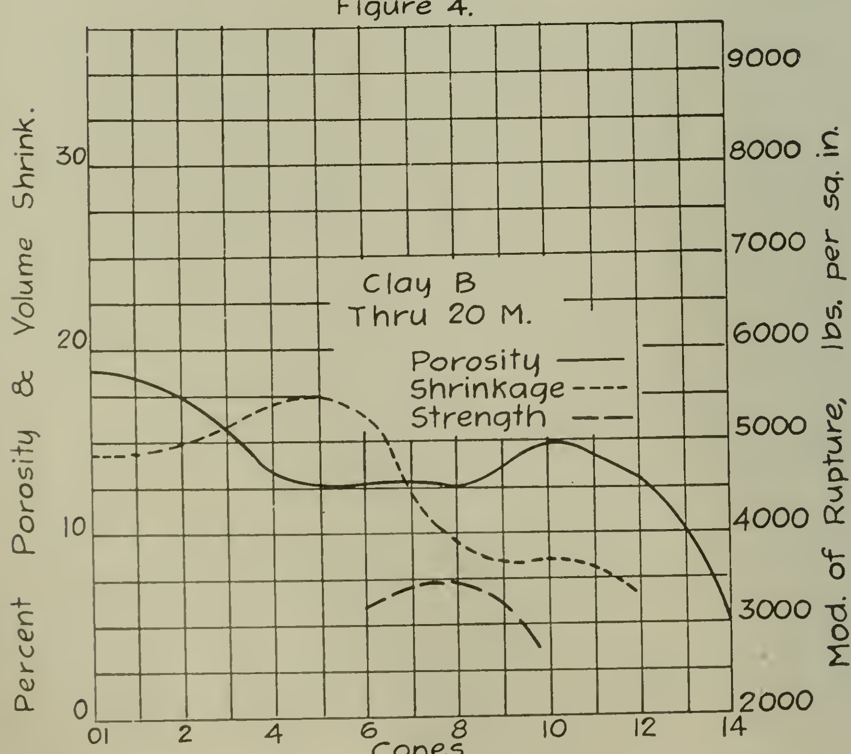


Figure 5

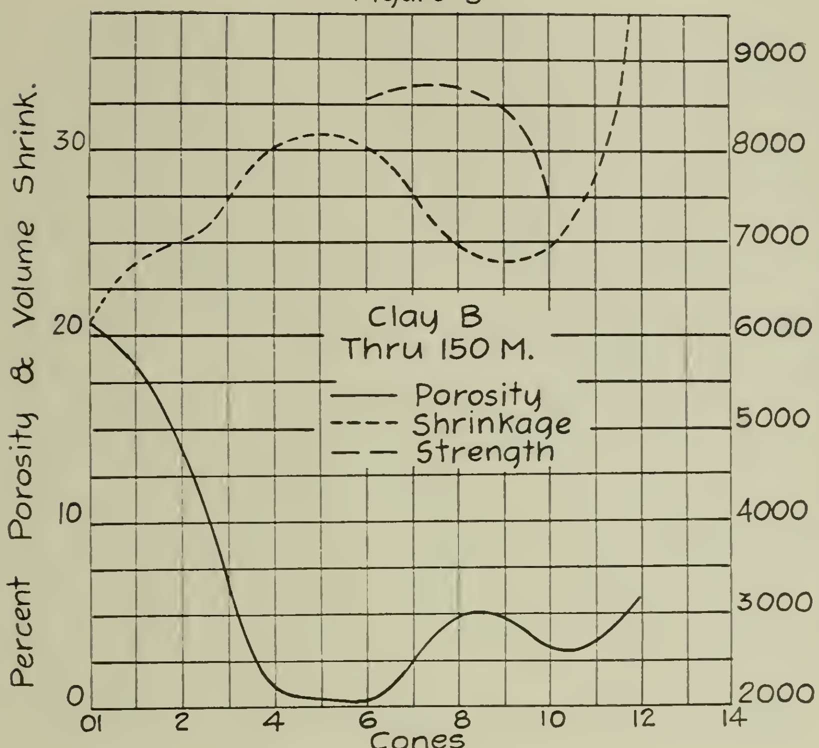


Figure 6.

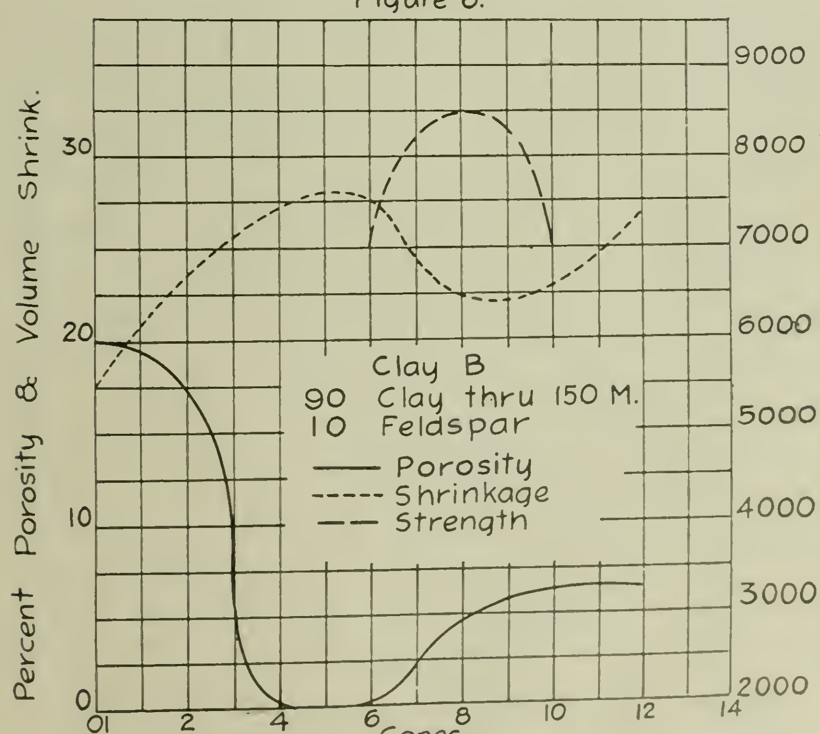


Figure 7

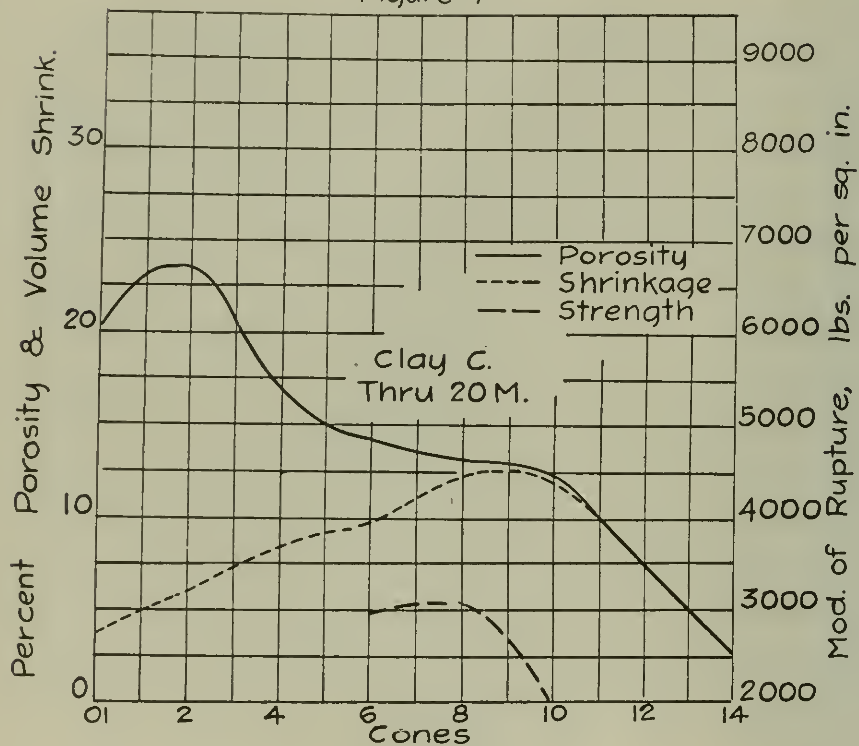


Figure 8

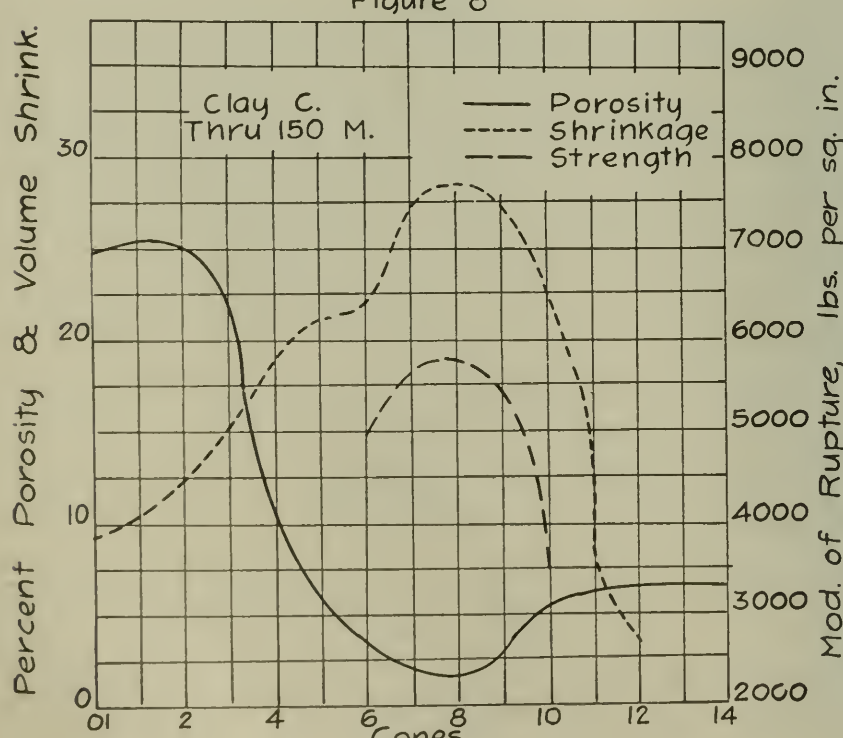


Figure 9.

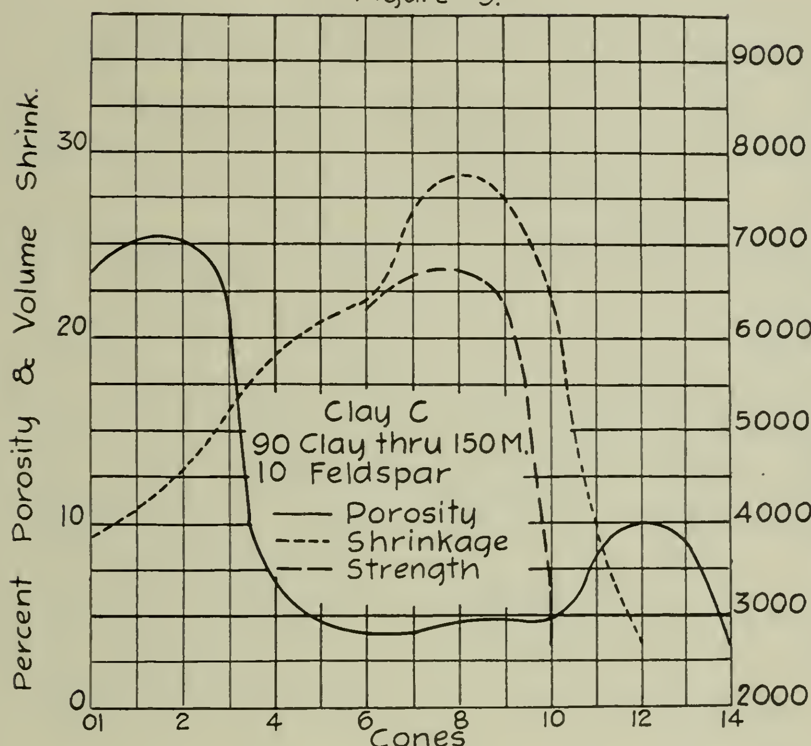


Figure 10

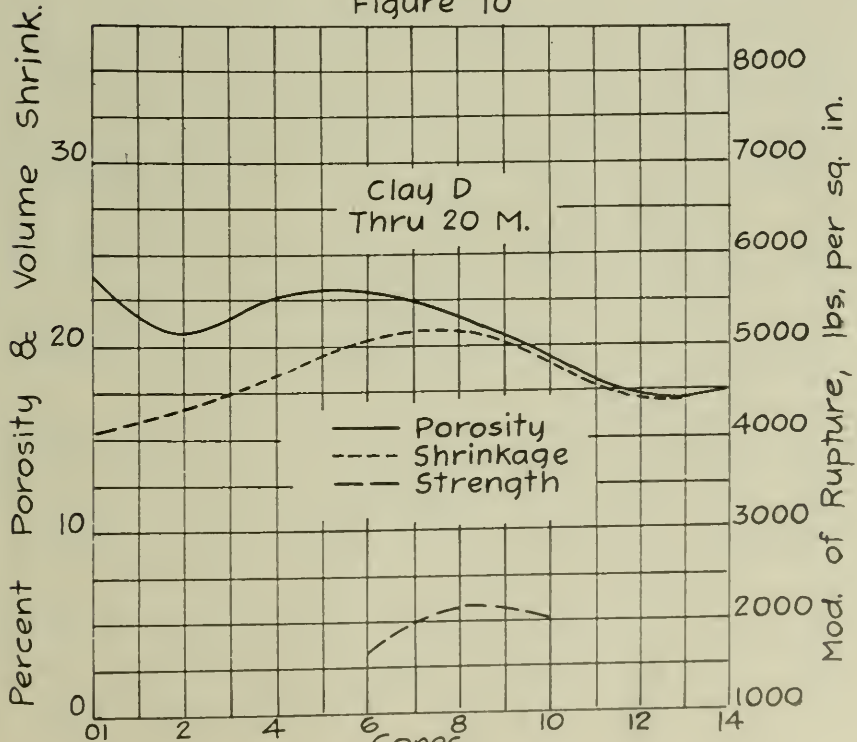


Figure 11

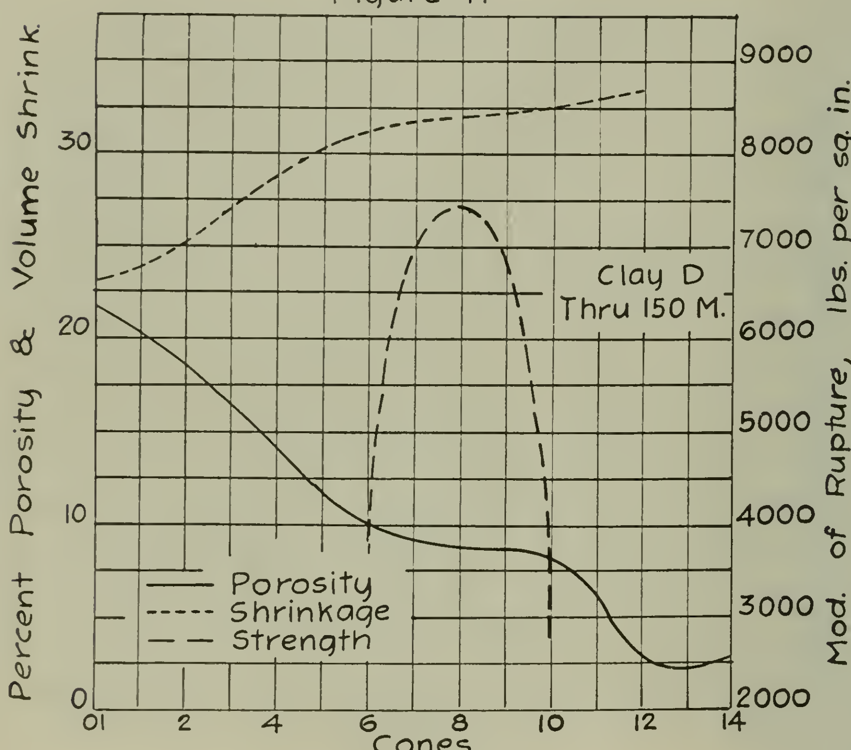
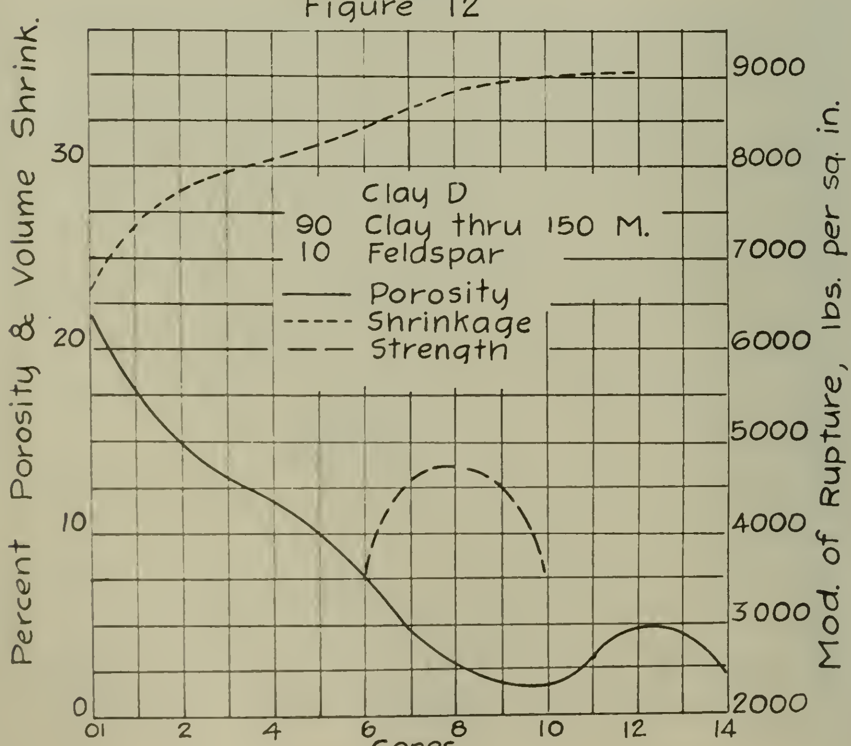


Figure 12



strength until they were fired at cone 8, although they had commenced to swell due to overburning at that temperature. The results observed in clays of this type are shown in figures 1, 3, 4, 5 and 6. In figure 2 is shown a similar clay in which the strength decreased when fired to cones 8 and 10, as would be expected. This, however, is an exception rather than the rule.

Table 1—Miscellaneous Properties of Clays and Mixtures Tested

	% porosity at cone 8	Mod. of rupture, lbs. per sq. in. dried at 100 °C.	Modulus of rupture, lbs. per sq. in. fired at			Ratio of mod. of rupture after firing at cone 8 to that when dried at 100°C.	Clays soften at cone No.
			cone 6	cone 8	cone 10		
Clay A through 20 M.	10.93	384.3	2788.7	3568.7	2260.0	9.30	26—
Clay A through 150 M	13.25	532.	7904.3	6847.5	5690.0	12.85	...
Clay A through 150 M —90, Feldspar —10.	5.69	...	5128.6	5191.6	4584.0	...	...
Clay B through 20 M.	12.48	218.6	3190.0	3416.2	2665.0	15.7	26+
Clay B through 150 M	4.97	...	8556.0	8680.0	7504.8	27.2	...
Clay B through 150 M —90, Feldspar —10.	4.77	...	7010.0	8482.0	7050.0	...	...
Clay C through 20 M	13.24	194.2	2911.2	3063.0	1909.0	15.8	28
Clay C through 150 M	1.03	191.0	4932.5	5815.0	3368.0	32.0	..
Clay C through 150 M —90, Feldspar —10.	4.44	...	6275.0	6727.0	2675.0	...	..
Clay D through 20 M	21.65	93.8	1649.4	2129.3	2041.0	23.0	32+
Clay D through 150 M	8.70	270.0	3655.0	7411.0	2716.0	27.4	..
Clay D through 150 M —90, Feldspar —10.	2.95	...	3585.0	4710.0	3567.0	...	..

Clay A—Lower Kittaning clay, Toronto, Jefferson County, Ohio.
Clay B—Lower Kittaning clay, Roseville, Muskingum County, Ohio.
Clay C—Lower Kittaning clay, New Brighton, Beaver County, Penna.
Clay D—Semiflint clay, Scioto Furnace, Scioto County, Ohio.

Other clays and mixtures developed maximum shrinkage, minimum porosity, and maximum strength at cone 8. Clays of this type develop more strength than those which are over or underfired at cone 8, although the latter show their maximum strength after firing to cone 8. Clay C, through 150 mesh, which is of the former type (see Fig. 8 and table 1), developed, by firing to cone 8, a strength 32 times that possessed in the raw state. This is a greater ratio than obtained with clays and

mixtures which over or underburn at cone 8. Clays developing maximum shrinkage and minimum porosity at temperatures higher than cone 8, but still having maximum strength at cone 8, are shown in figures 7, 10, 11 and 12. The tendency of these bodies to weaken when fired above cone 8 may be due to the formation of sillimanite which begins to develop about the temperature.

It is therefore evident, that *maximum cross-breaking strength is developed by selecting a body which has maximum shrinkage and minimum porosity when fired at cone 8.* The observations so far have been made on fire-clays and bodies of the fire-clay type. Whether the results obtained on these clays and mixtures are in accord with those of porcelain and whiteware bodies will be determined later.

THE WATER SMOKING OF CLAYS[1]

By R. F. Geller

ABSTRACT

Experimental Method.—The water smoking behaviors of two plastic brick clays, one shale and one fire-clay were studied by heating 4-in. cubes at different rates, two thermo-elements being buried in the brick and two others placed against the exterior surface.

Results of Conclusions.—To save time in water smoking, the ware should be previously dried not far from 100 °C, good circulation should be provided in the kiln and the temp. of the interior of the product should not lag appreciably behind that of the kiln. It should be possible to water smoke heavy clay products in 15 hours with heating rate of 20 °C per hour.

Introduction

The introduction of the tunnel kiln and the general necessity of cutting down the time consumed in burning make it desirable to study the water-smoking process in greater detail than has been done in previous work and to establish the minimum time required for the expulsion of the hygroscopic water. This involves also the study of the thermal changes taking place in clay and the establishing of the minimum temperature necessary to drive off this last portion of the mechanically held water. The work, in brief, consisted in following the temperature lag due to the presence of the residual water both with reference to the magnitude of the lag and its connection with any critical temperatures.

The materials studied were two plastic brick clays from the District of Columbia Workhouse, which are of an exceedingly tough structure and retain water very tenaciously; a shale from Milton, Pa., and one from the District Workhouse; and one fire-clay from Lester, Arkansas.

The plastic clays were chosen for this purpose oweing to their exceedingly well developed plastic structure. Each sample was ground to pass the 20-mesh sieve, pugged thoroughly to a stiff plastic consistency and pressed by hand in molds to form

[1] Received Feb. 14, 1921; published by permission of the Director Bureau of Standards.

four-inch cubes. Some of the specimens were previously dried to constant weight at 50°C before being subjected to the water-smoking treatment. Others were air-dried in the laboratory from one to five days at atmospheric temperature.

The water-smoking process itself was conducted in an electrically heated oven, the inside dimensions of which were 8 × 8 × 12 inches. In each run the test piece was placed in the center of the furnace thus permitting free circulation of air on all faces of the cube. The furnace temperatures were read by means of copper-constantan thermo couples in contact with the upper and lower surfaces of the cube. A gentle current of air was provided for the removal of the steam. The temperatures within the cube were obtained from two thermo couples embedded within the piece at depths of one and two inches, respectively. All the temperature readings were recorded by means of a multiple point potentiometer. The maximum temperature to which the specimens were carried was 300°C. The duration of the water-smoking treatment was varied from three to eighteen hours.

Experimental

The results obtained are illustrated in the diagrams of figures Nos. 1 to 16, and these curves will be discussed in order in the following paragraphs:

Figure 1.—This specimen made from the plastic brick clay, as well as those immediately following, was dried to constant weight at 50°C previous to the water-smoking treatment. The furnace was brought to 300°C in three hours. It will be observed that beginning with room temperature the lag between the furnace temperature and that of the cube increases steadily, indicating increased heat absorption by the clay. This condition continues after the furnace has reached the maximum temperature. It is interesting to note that there was practically no lag between the points one inch distant within the cube, showing that the conductivity of the clay is very much greater than we should expect since even with this fast rate of heating there was such complete equalization. It is evident, however, that the rate of heating was entirely too fast.

Figure 2.—In this experiment we have the same clay, the

plastic material from the District Workhouse, and it will be observed that although the time of drying has been doubled the area of heat absorption does not tend to diminish appreciably, indicating that considerable heat work is being done in removing

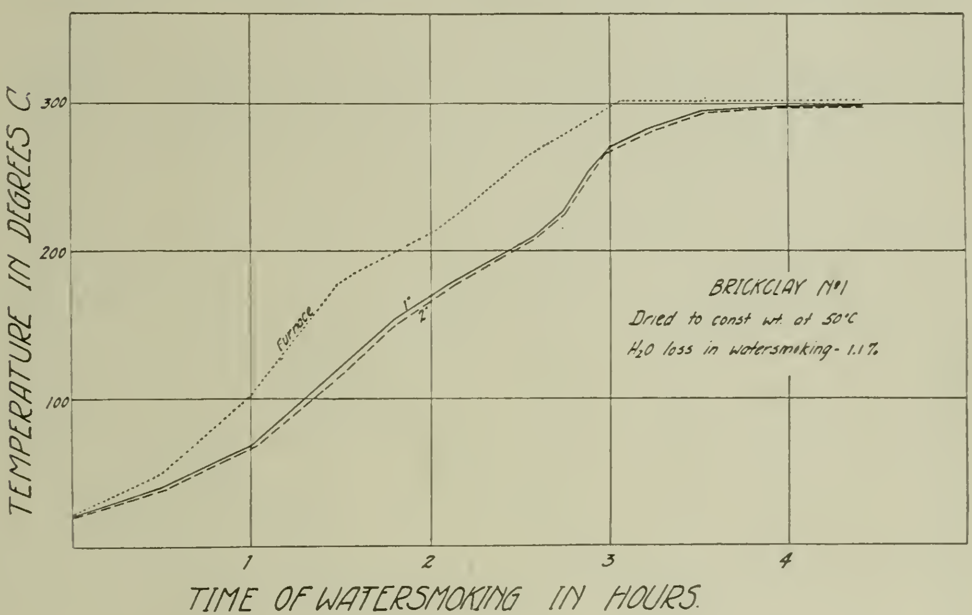


Fig. 1

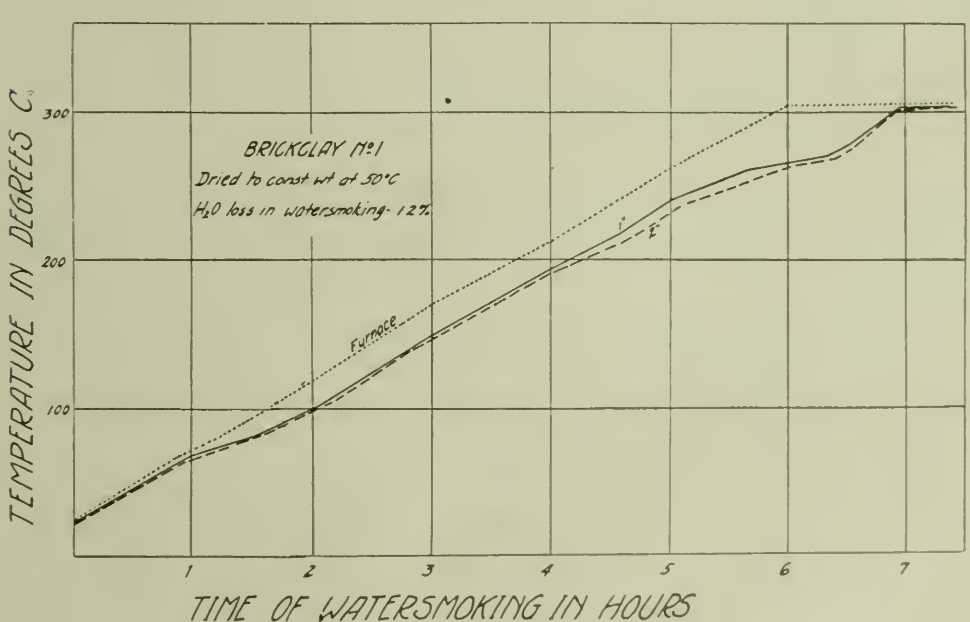


Fig. 2

the hygroscopic water and that the rate of heating is still so fast that there is a decided lag between the furnace and clay temperatures.

Figure 3.—Here again we have the same clay previously dried to 50°C but heated to 300°C in 12 hours. It will be observed that the temperature lag is nearly constant throughout the run and that the temperature of the cube coincides with the furnace temperature only after one hour's heating at 300°C. The inflections of the cube temperatures shown in the curves of

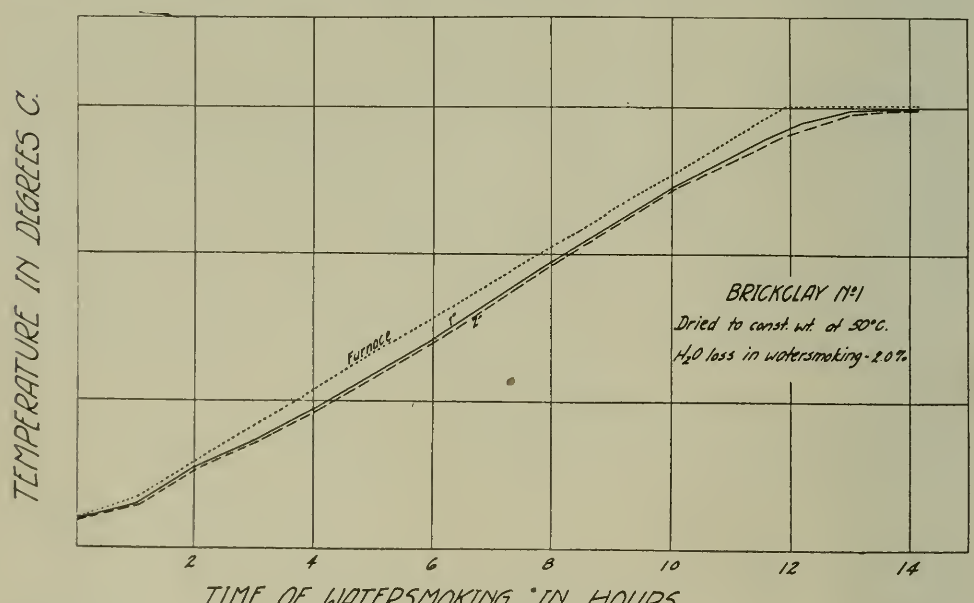


FIG. 3

figures 1 and 2 at approximately 80°C and 280°C have been smoothed out although there is some indication of the higher lag point.

Figure 4.—The material represented by this diagram is a soft shale which shows an even greater heat absorption than the clay previously discussed but gives indications of reaching thermal equilibrium somewhat more rapidly.

Figure 5.—This diagram again represents the plastic brick clay discussed above but with a water-smoking run of 15 hours. This rate of heating thus has removed the lag so apparent in the previous diagram, inasmuch as the temperatures of the clay followed the furnace temperature very closely, thus indicating

that the heat requirements of the clay at each particular point are met by the furnace with sufficient promptness. It is evident that such a condition of gradual and constant vaporization tends to carry through the process without undue strains due to the

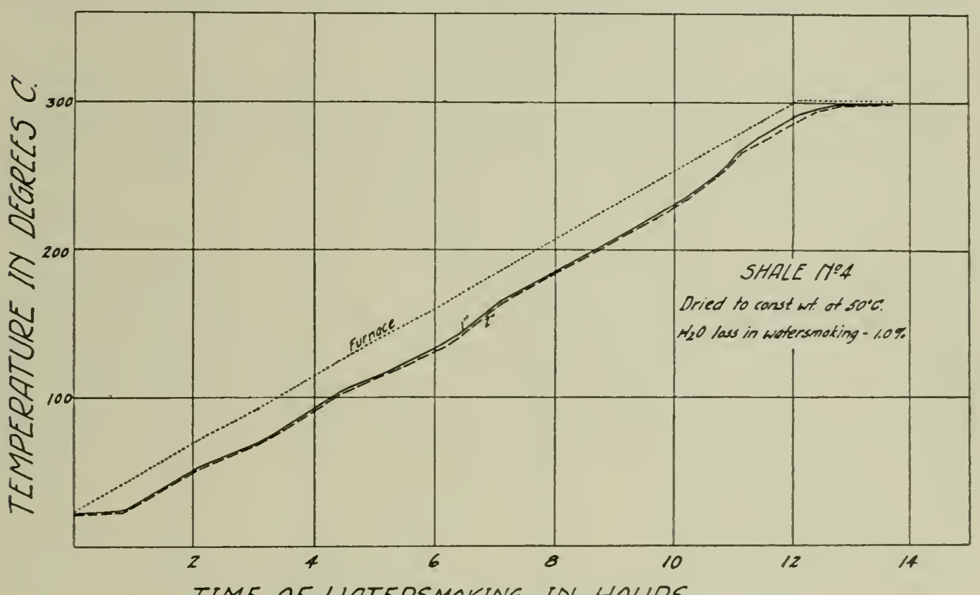


Fig. 4

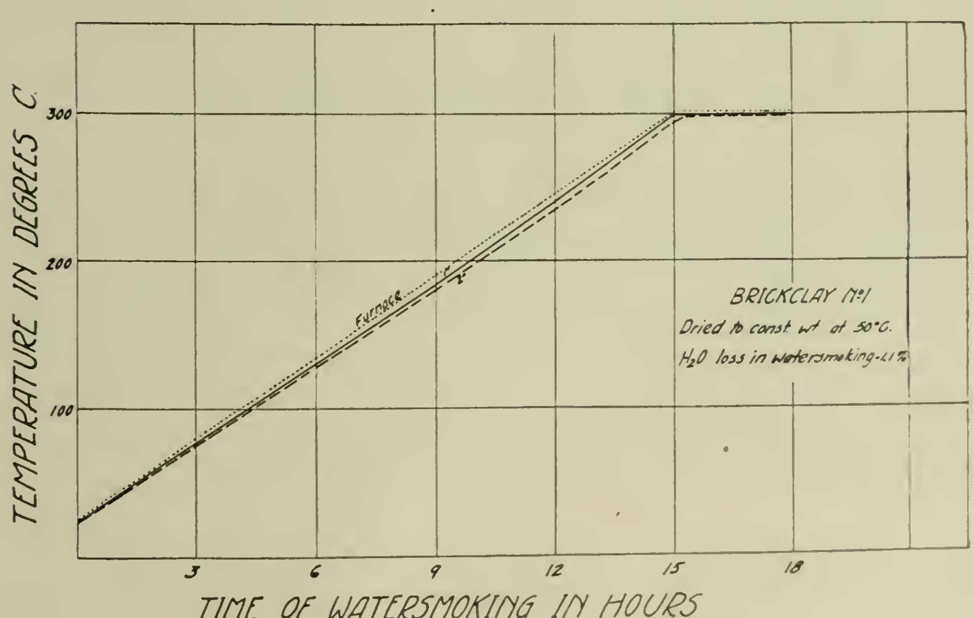


Fig. 5

temperature differences between the surface and the center of the cube. Such a condition is therefore very desirable in actual burning operations.

Figure 6.—This diagram represents another of the very plastic brick clays, studied with a high content of hygroscopic water,

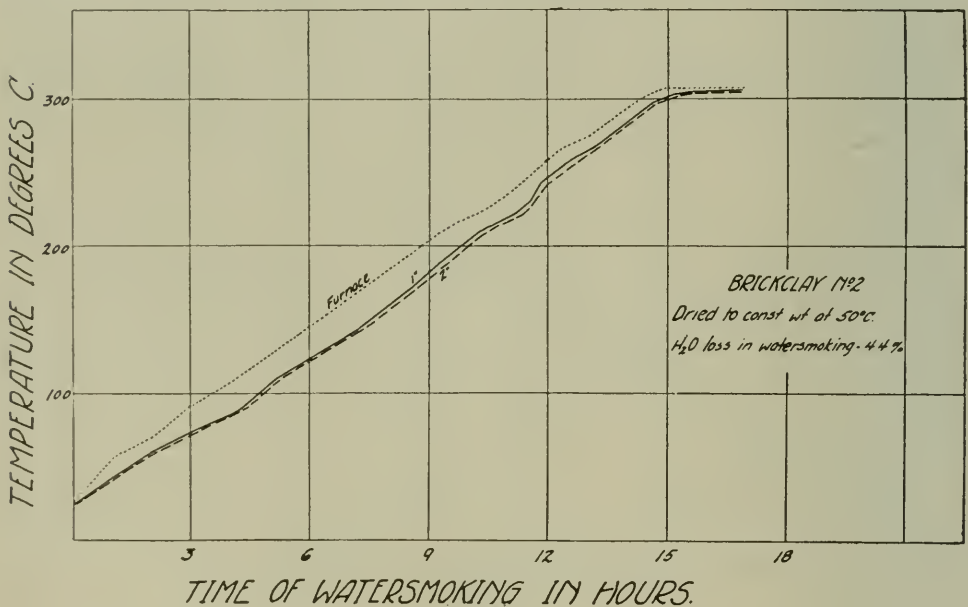


FIG. 6

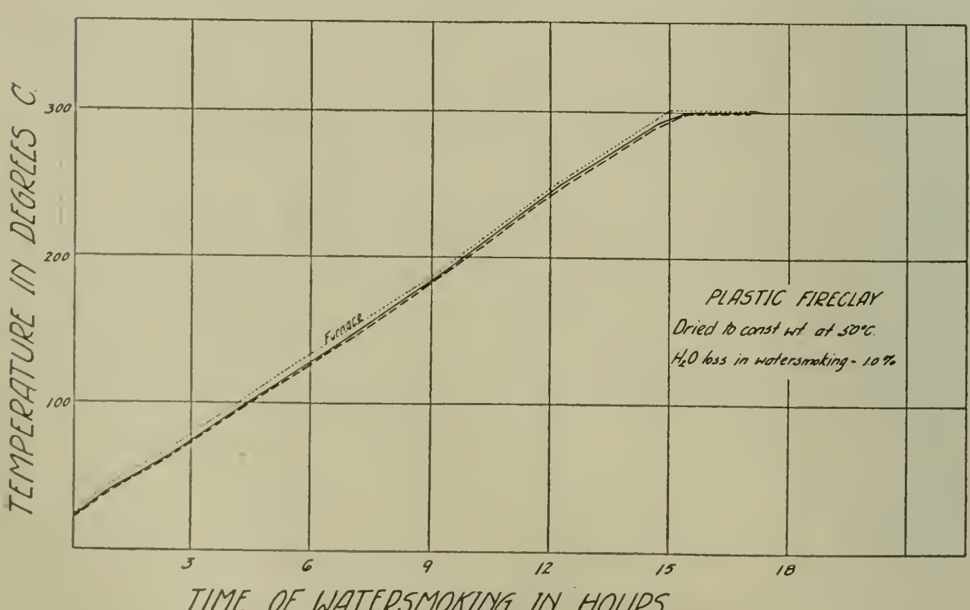


FIG. 7

approximately 4.4 per cent. Here again the duration of the run was 15 hours, but the high water content has been found to cause a distinct lag which persists up to the maximum temperature. The increasing lag between the two cube temperatures towards the end of the run would indicate decreased heat conductivity brought about by the drying out of the clay.

Figure 7.—These curves represent the heating up of the plastic silicious fire-clay containing one per cent of hygroscopic water. It is observed that there is only a slight lag between the tempera-

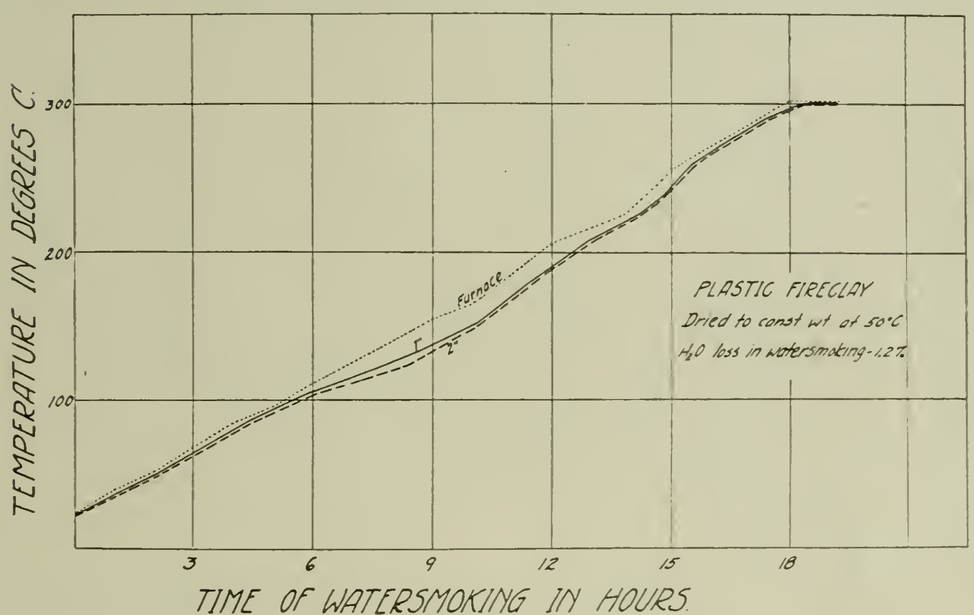


Fig. 8

tures of the furnace and of the clay specimen, indicating that this rate of heating provided all the thermal energy required for water smoking without any appreciable temperature difference within the cube. The heat treatment, therefore, is entirely normal and satisfactory.

Figure 8.—Representing the same fire-clay but with a slightly higher content of hygroscopic water, this diagram is of interest inasmuch as it indicates the temperature limits between 100 and 250°C.

It was then decided to determine the temperature range between which the process of water smoking takes place and at the same time fix the critical temperatures involved with greater cer-

tainty. It was evident from the previous work that clays previously dried to 50°C would not show these facts with sufficient emphasis, owing to the low content of hygroscopic water. For this reason it was decided to use the clays in the air dried state, after drying from one to five days at atmospheric temperature. In several cases the air drying was carried to constant weight, which required a week or longer.

Figure 9.—This diagram represents the brick clay No. 1, dried four and a half days at room temperature. The rate of water smoking was very rapid and in fact too rapid to show the

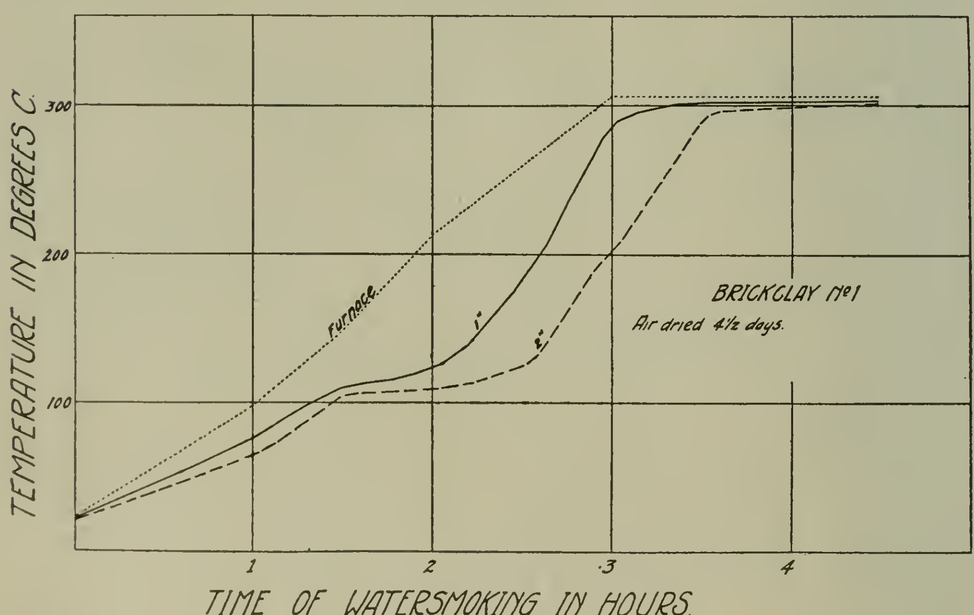


FIG. 9

critical temperature involved with sufficient accuracy. It is evident that owing to the rapid rate of heating these temperatures are displaced upwards and equilibrium between the furnace and the specimens is not attained until after prolonged heating at 300°C. As should be expected, due to the relatively high water content, the heat absorption area between the furnace curve and the clay curve is very large. There is likewise a considerable lag between the two points within the cube. From the appearance of the curves it is evident that considerable pore water is still present in the clay, since the thermal lag is apparent

from the very beginning of the heating. It would seem, however, from the configuration of the curves that the typical water-smoking temperature range lies between 100°C and some point below 300°C. For this reason it was decided to subject the same clay

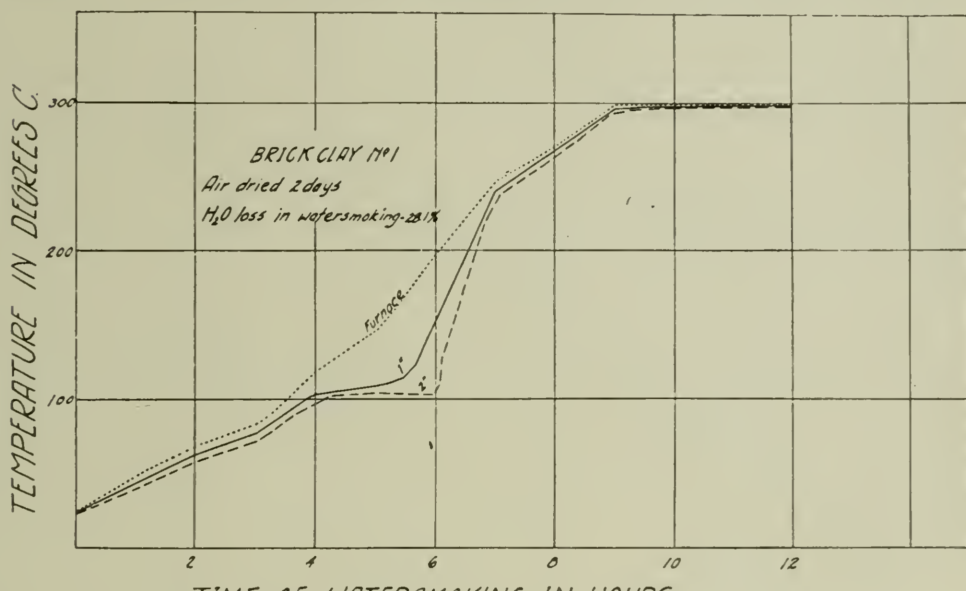


Fig. 10

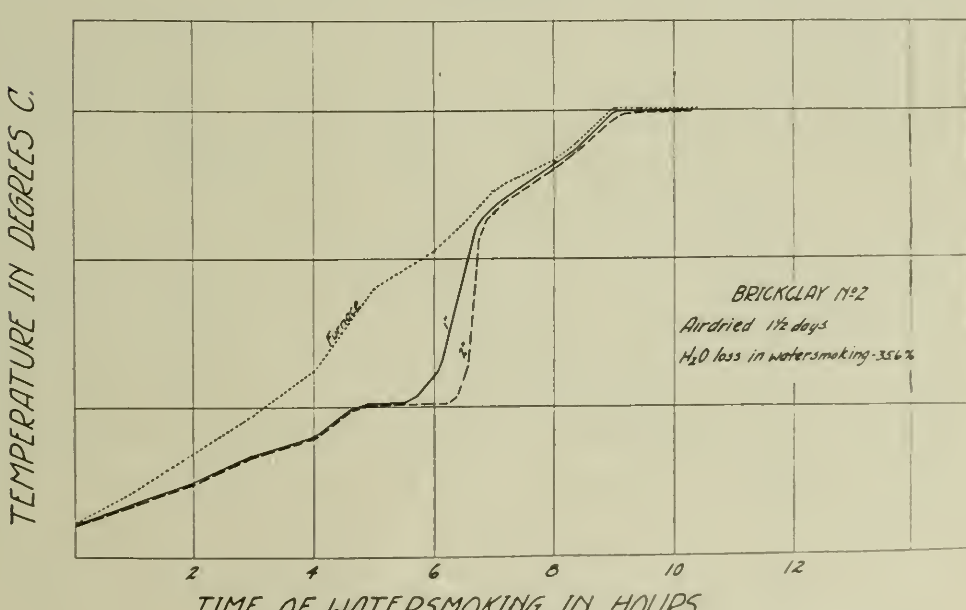


Fig. 11

specimen, dried only two days, to a less rapid heat treatment, taking nine hours to reach 300°C.

Figure 10.—Here brick clay No. 1 still containing about 28 per cent of water shows the thermal lag to lie between 100 and 240°C, which gives us the desired information for a case of this kind.

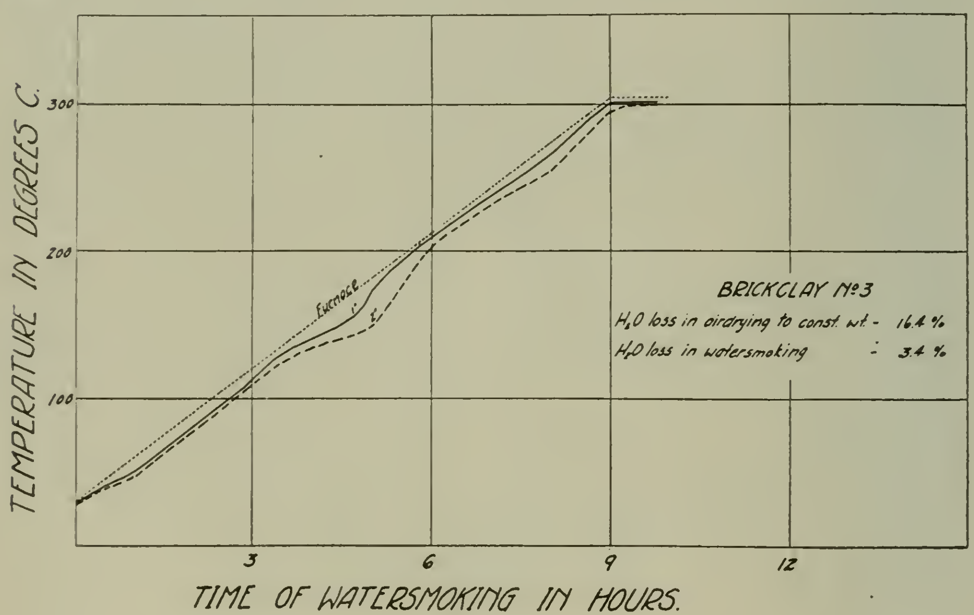


FIG. 12

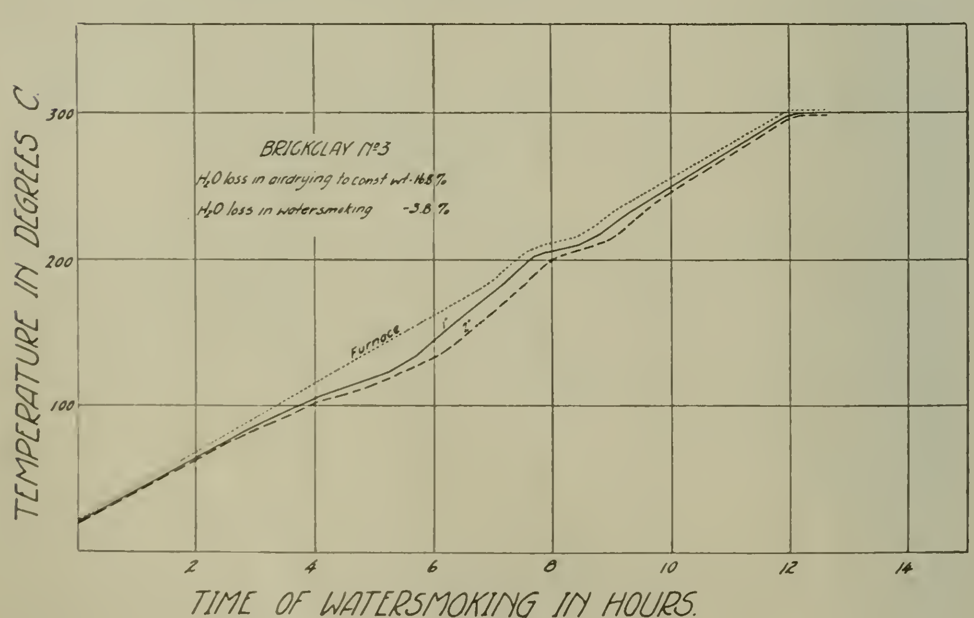


FIG. 13

Figure 11.—In this case we are dealing with brick clay No. 2 which is of the same type as No. 1 and which still contains 35.6 per cent of water. The heat absorption again, neglecting the pore water proper, is included between 100 and 240°C.

Figure 12.—This diagram represents a brick clay dried at atmospheric temperature to constant weight and then subjected to a water-smoking treatment of nine hours. The lower heat absorption limit is found to be above 100°C and the upper one at approximately 250°C.

Figure 13.—This diagram represents again brick clay No. 3, previously air dried to constant weight and still containing 3.8

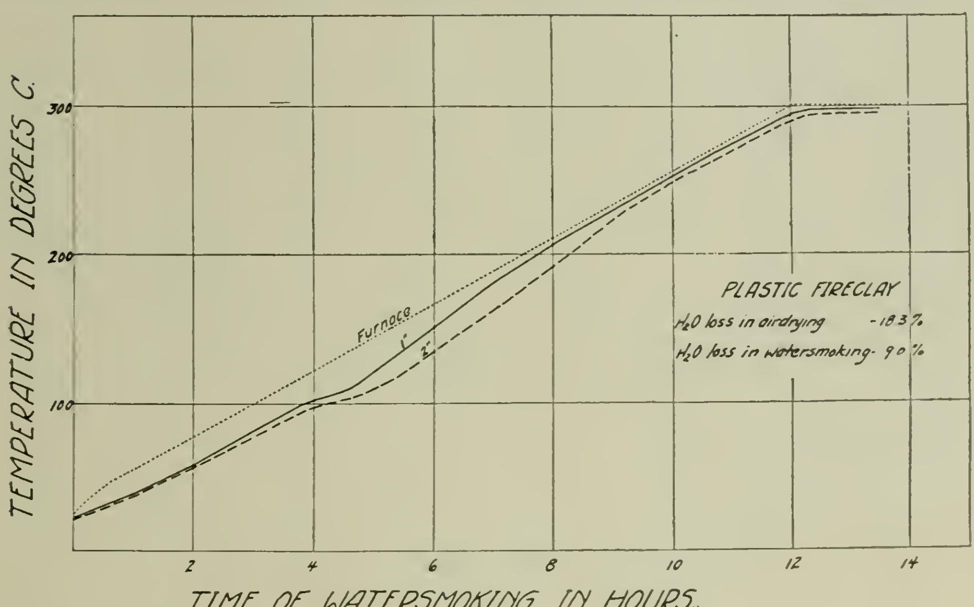


FIG. 14

per cent of water, the rate of heating being slowed down and the heat treatment extended to 12 hours. Here the temperature lag is included between 100° and approximately 240°C, and it would seem that this point is independent of any previous drying treatment to which the clay has been subjected. Since the lag between the furnace and the clay temperature is not excessive and hence not likely to cause inordinate strains, it appears that 12 hours time is required to expel the hygroscopic water.

Figure 14.—In this diagram we have the plastic fire-clay with a water content of 9 per cent at the beginning of the water smoking.

From this greater content of water it would appear that there must be considerable lag between the furnace temperature and that of the cube as well as between the two points within the latter. Owing to the presence of pore water the heat absorption must obviously extend to a point below 100°C, while the heat absorption due to the hygroscopic water is again included between 100 and 240°C.

Figure 15.—In this diagram and the one following, extreme cases were taken in which the air drying was conducted only through one day and through a half day, respectively. In the

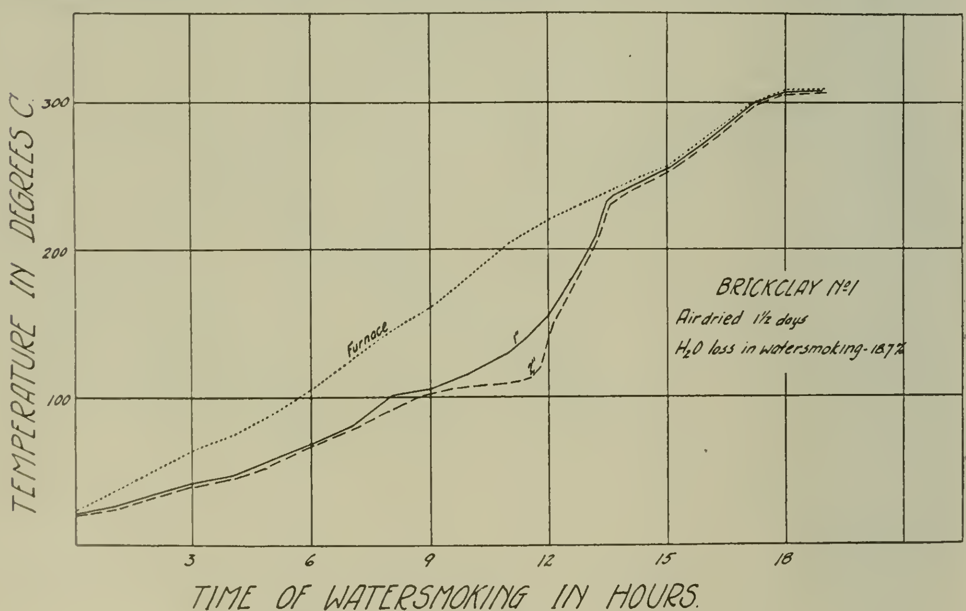


FIG. 15

present case (brick clay No. 1) the material still contained 18.7 per cent of water. The heating was conducted at quite a slow rate, covering 18 hours. It is evident that in this case there is considerable overlapping in the expulsion of the pore and hygroscopic water since the former could not be completely driven off in the time allowed before reaching 100°C. The thermal lag, therefore, is very large and the test specimen must necessarily have been subjected to a decided strain. However, the critical temperatures are again, as indicated before, between 100 and approximately 240°C. It is interesting to note that even under these conditions the water smoking was completed in about $13^1/_2$ hours.

Figure 16.—In this diagram we again have the silicious fire-clay but air dried only for one day with the result that the temperature lag and the area of heat absorption are very marked. Overlapping of the evaporation of pore and hygroscopic water again occurs and there is a decided drop in temperature between

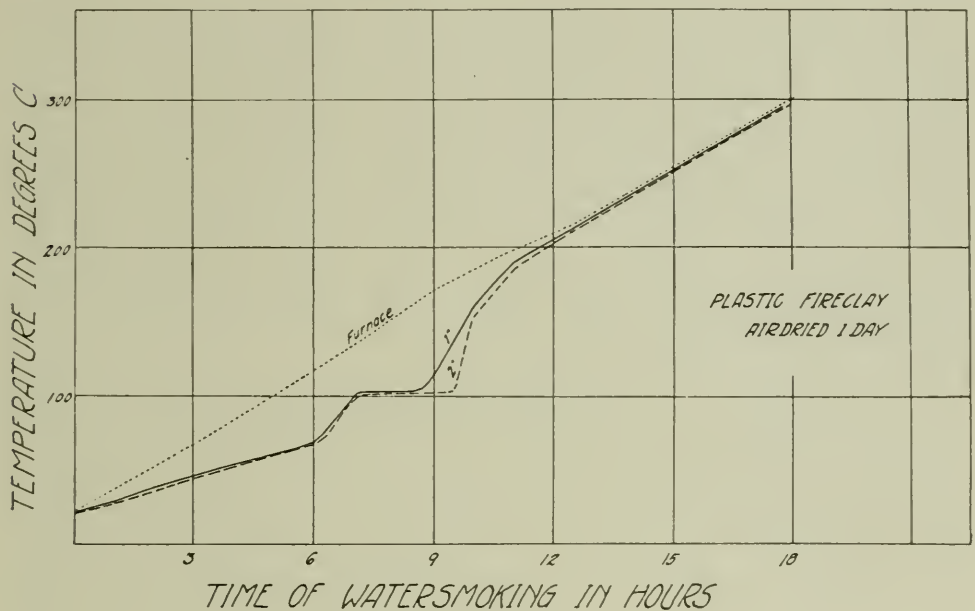


Fig. 16

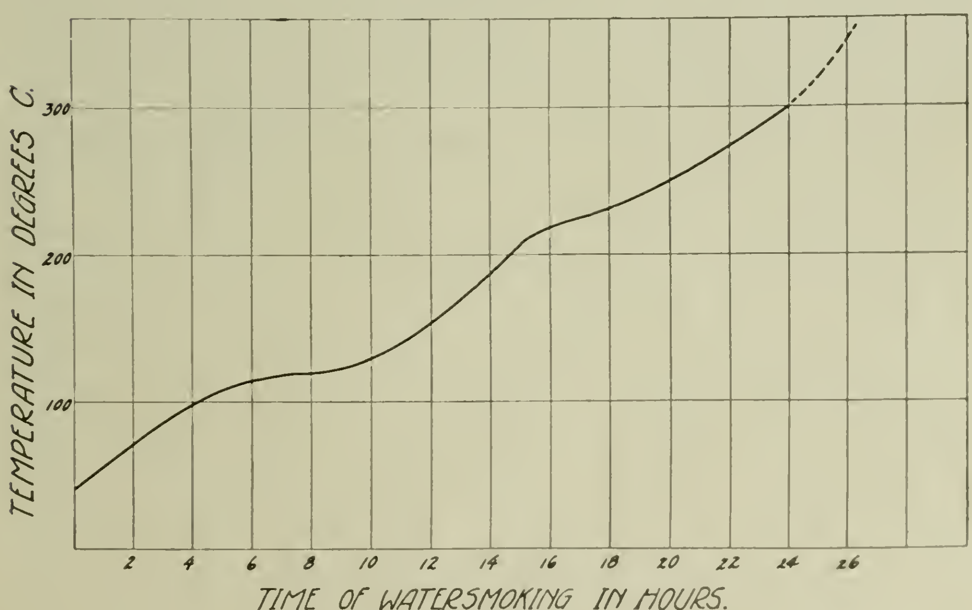


Fig. 17

the surface and the interior of the test piece, a condition which is obviously objectionable but would not have occurred if the clay had been previously dried sufficiently.

Conclusions.—From this work the following conclusions may be drawn:

For the purpose of expediting the water smoking of clay products, it is necessary to dry the ware thoroughly and as close to 100°C as possible, a statement which agrees with practical experience. It is also obvious that the permissible rate of drying is a function of the surface of the product referred to unit volume. In other words, thin ware can be dried very much more rapidly than products of heavy cross section. The four-inch cubes employed in this study are comparable with the heavier clay products such as bricks.

It is necessary, in water smoking as rapidly as possible, that the steam which is produced be removed promptly. In practice a great deal of time is lost due to the poor circulation prevailing in the kiln at the beginning of the burn. The importance, therefore, of having ample stack draft through the use of higher chimneys or such which are kept heated at the beginning of water smoking is evident. Our down draft kilns, for instance, invariably suffer from very poor initial draft, a condition which is paid for by the loss of valuable time. Not only is the water smoking process proper retarded by the deficiency in draft but it may be greatly lengthened through the absorption of steam by the ware in the cooler portion of the kiln. Such a condition greatly aggravates matters since, so to speak, a new start must be made in order to expel the accumulated excess water taken up by part of the kiln charge. It would be a good investment, therefore, to provide, if necessary, mechanical draft through the use of portable exhausters. The rate of raising the temperature during the water smoking should be such that there is no marked difference between the kiln temperature and that of the interior of the product. An excessive rate of heating invariably causes strains which may lead to damaging of the ware. The permissible rate of heating varies somewhat with the clay structure, that is, with the amount of hygroscopic water carried by the clay and with the artificial structure imparted to the material in pressing.

It is evident that clay particles possessing but limited cohesion, as in dry pressed ware, can not withstand the strain brought about by a decided temperature difference between the exterior and the interior temperature of the ware. Very slow drying becomes imperative in such a case. However, in the case of plastic clays previously dried sufficiently, it would seem that the water smoking should be completed in 15 hours when heated to 300°C, or at the rate of 20°C per hour. Provided that adequate circulation is maintained there is no reason why this should not be done, even in the case of heavy clay products. The industrial importance of this statement is apparent and is worthy of careful consideration.

The temperature range of water smoking lies between 100 and approximately 240°C for properly dried material. Overlapping of the heat absorption ranges involving the pore and hygroscopic water occurs upon insufficient drying.

Allowing 24 hours for the completion of water smoking, satisfactory results may be obtained by increasing the temperature at the rate of about 12°C per hour, or by following such a heating curve as is suggested in the diagram of figure 17. The use of base metal thermocouples is, therefore, strongly recommended for the proper control of this important process.

The writer desires to acknowledge the help of Mr. A. V. Bleininger in outlining this work and reporting the results.

Bureau of Standards
Washington, D. C.

REFRACTORIES FOR OIL-FIRED FURNACES AND BOILERS[1]

By W. H. Grant

ABSTRACT

The failure of fire-brick in oil fired furnaces results from (1) *spalling* and falling of side wall bricks, (2) *disintegration* of bricks in direct path of flame, (3) *glazing* of surface with green glaze which penetrates and weakens brick, and (4) *erosion* by flame. A plea is made for more research in the field.

The question as to the proper grade of refractory material for use in connection with oil burning furnaces of various types deserves more attention than it has apparently received in the past. So far as the writer has been able to learn, very little has been written on this subject and no great amount of research work has been done. In some localities and in some lines of industry, fuel oil has practically replaced coal, natural gas and other fuels, while in others where the cost of oil is high and coal and gas are cheap and easily obtained, the use of fuel oil is more limited. A recent report made by the Geological Survey discloses that between April 1, 1919, and March 1, 1920, the coal consumption displaced in 317 electric utility plants and 2347 industrial plants was approximately 1 per cent. The electric utility plants mentioned represent about 50 per cent of the total consumption of electric utilities and the 2347 industrials represent about 37 per cent of the total consumption of general industries, excluding steel mills and by-product coke plants.

While it is true that only a small per cent of the fire-brick and other refractory material consumed go into oil fired furnaces, nevertheless the question of the proper refractory for this class of service is of vital importance to the plant or power house operating with oil. This question is equally important to the manufacturer who is endeavoring to furnish the refractory material used. Doubtless all manufacturers of fire-brick have been called upon at some time or other to furnish a lining for an oil burner and they may have met with fair success or otherwise. I doubt very much, however, if these same manufacturers can point out definitely just why the particular brick they furnished was suitable for the job in question, or why another of their brands

[1] Received March 10, 1921.

would not have answered just as well or perhaps better. I doubt if they can answer conclusively why they furnished a handmade brick instead of one made by machine or why a dense, tough, hard-burned brick instead of a softer brick of open porous structure or vice versa. And yet what manufacturer will refuse to furnish a brick for this purpose when called upon to do so? They will, to be sure, do the best they can to supply the requirements of the purchaser, but in many instances their selection is no more than a wild guess.

The question then seems to be, "Why is an 'oil-brick,' " or in other words, "What properties must a brick have to make it suitable for use in oil-fired furnaces?" Before answering this question there are several other questions to be taken into consideration. Why do side wall bricks spall and drop out of place, thus weakening the wall? Why do the brick in the direct path of the flame become lifeless, disintegrate and fall to pieces after being in service but a short time? What it is in the oil flame itself or in the atmosphere of the combustion chamber that glazes over the outer surfaces of the brick work in some places and permeates the brick in others, causing high discoloration and probably some disintegration? Why are some brick badly eroded and flame cut in the direct path of the flame while others of approximately the same refractoriness are not affected? These and a number of other questions are presented to the man who is called upon to investigate the fire-brick service conditions in industrial plants where the brick are not proving satisfactory.

Very frequently the fault lies with the design of the furnace or with the method of operation but it is a very difficult proposition to place the blame when the refractories are going bad. The refractories manufacturers' best safeguard in all cases is to make a thorough and comprehensive study of the service conditions under which his products are to be used and then to supply material best suited to this work. A manufacturer must determine from practical experiments which of his grades of brick are most suitable—whether handmade or machine made, whether dense or porous, whether coarse ground or fine and whether burned soft or hard. Some brick made by hand, ground fairly fine, and burned hard, give excellent results in some installations,

while other brick of equal refractoriness composed of different clays and manufactured by machinery, ground fairly coarse and of a so-called medium burn, appear equally satisfactory.

The writer recently had the opportunity of inspecting a large water tube boiler installation which was equipped with one of the newer types of fuel oil burners. In order to run comparative service tests, three different boilers of the same capacity and of identical setting-design were lined with three different brands of high duty brick, which were known to the trade as being suitable for oil furnaces. So far as the writer was able to learn, all these brick had been used quite extensively in connection with oil furnaces and had proven satisfactory, but at the time of the investigation all three of these brands in the different boilers had failed badly.

The side walls had spalled off to a depth of several inches, allowing the super-structure to settle. Particles of brick which had fallen out were badly discolored by gases or vapors which had penetrated to the interior of the brick. All other parts of the side wall were glazed over with a beautiful deep greenish blue glaze which rivaled art pottery decoration. The bridge-wall was flame cut and pitted to some extent though there was evident no sign of actual fusion, although the temperature in the combustion chamber was reported to exceed 3000°F. by pyrometer determination.

One brand of brick was a machine-made brick of open structure and rather soft burn from the Missouri fire-brick producing district and the other two were Pennsylvania handmade brick of medium grain—one hard burned and the other considerably softer. In all three bricks, however, the results were practically the same. The writer has thus far not been able to answer the "why" in this case, nor has the chief engineer of the plant under whose immediate supervision these tests were conducted.

This experience is just a sample of the problems which confront the manufacturers and the consumers of "oil brick" and clearly demonstrates the necessity of intelligent research work in this field. It is the writer's candid opinion that the Refractories Division of the American Ceramic Society should go into this question and have at least one good paper prepared and read before the next general meeting.

NATIONAL REVIEW OF THE SAGGER SITUATION[1]

By George Simcoe

ABSTRACT

A questionnaire sent to a number of clay mfgs. elicited the information: (1) better *sagger cost system* needed; *carborundum* and Na SiO are frequent constituents of the sagger body; (3) jaw crusher better than pan grog; (4) sagger containing 30 per cent carborundum and lasting 20 or more fires is economical.

Having sent a questionnaire to a number of clay-ware manufacturers throughout the United States, I have listed their replies to the twenty-five questions in a chart form, grouped as follows:

2 Spark Plugs
6 Wall and Floor Tile
3 Sanitary Ware
4 General Ware
2 Vitrified China
2 High Tension Insulators
1 Art Pottery
1 Chemical and Scientific Porcelain
3 Grinding Wheels and Abrasives
4 Electric Porcelain

Ten Points Noted From the Above Chart

No. 1. Out of 28 answers only 11 give average sagger cost. It looks as if we should have a better sagger cost system. One sanitary pottery reports sagger cost 18 cents.

No. 2. The addition of 10 to 30 per cent carborundum is quite common just now. See samples 6–10–20.

No. 3. The addition of sodium silicate reduces the amount of water necessary to make plastic and gives strength to the dried sagger before firing. See samples 6A–10A–20A.

No. 4. A cast sagger having sodium silicate and carborundum incorporated. See sample.

No. 5. Jaw crusher better than pan grog. See sample grog.

No. 6. Why does the introduction of carborundum increase the life of the sagger?

[1] Received March 10, 1921.

1. Ware Manufactured?	Spark Plugs 1	Spark Plugs 2
2. Kind of kiln?	10″ D Dft.	Con. tunnel
3. Fire to what cone?	Cone 9	Cone 17
4. How long cool?	50 hrs.	24 hrs.
5. How make saggers, hand or machine?	Hand	Hand
6. If machine, split or solid ring?	....	....
7. Do you level or finish machine made saggers?	....	....
8. Do you make saggers day, wk., or pc. wk.?	Day work	....
9. Do you wash saggers day, wk., or pc. wk.?	Not washed	....
10. Are saggers bone dry when fired?	Air dry	Bone dry
11. Do you fire any ware in green saggers? If so, what part of full load?	No	No
12. Give average size, shape and cost of sagger used. (Thickness, sides & bottom).	10″ dia., 4″ high, 7/8″ thick, cost, ...	15″dia., 3 1/2″ high, cost ....
13. Average weight of ware per sagger?	8 lbs.	....
14. Average number fires sagger lasts?	No record	50
15. Average % sagger loss?	No record	....
16. Sagger body: % Plastic, cost inc. frt.	1/3 P $15.00 T	
% Sandy, cost inc. frt.	1/3 S 12.50	....
% Grog, cost inc. frt.	1/3 G	
17. What % of grog is: Coarse	1/3–3/16 to 1/4	
Fine	1/3 medium	....
Dust	1/3 dust	
18. Do you use any carborundum, alundum, zircon or similar body in saggers?	No	Carborundum
19. Do you use any sodium silicate in sagger body?	No	No
20. Do you use any other materials in sagger body not mentioned? If so, what?	No	....
21. What pug mill do you use?	Dry grind clay and mix in box	....
22. Do you pug twice?	....	....
23 Do you have a special foreman in charge of sagger dept.?	No	....
24. Have you ever tried using a special shaped grog? If so, will you give us your experience?	No	....
25. If you had the money and facilities what would you do to improve your saggers?	Expect to put in wet pan and pug mill	....

1. Ware Manufactured?	Wall and Floor Tile					
	1	2	3	4	5	6
2. Kind of kiln?	Rd. D. Dft.	14′ Dft.	Up & D. Dft.	Rd. D. Dft.	Rd. D. Dft.	D. Dft.
3. Fire to what cone?	Cone 11	Cone 1, 6, 9 and 12	Cone 10	Cone 11	Cone 11	Cone 11 D
4. How long cool?	5 days	60 hrs.	$3^1/_2$ to 4 da.	2 to 3 da.	2 to 3 da.	72 hrs.
5. How make saggers, hand or machine?	Machine	Hydraulic Press	Machine	Machine	Machine	Machine
6. If machine, split or solid ring?	Solid	Split	Solid	Split	Solid	Solid
7. Do you level or finish machine made saggers?	Remove rough edges—dry	Level & finish with great care	Yes	Level only	No	No
8. Do you make saggers day, wk., or pc. wk.?	Pc. wk.	Day wk.	Day wk.	Pc. wk.	Day wk.	Day wk.
9. Do you wash saggers day, wk. or pc. wk.?	Pc. wk.	Day wk.	Day wk.	Pc. wk.	Day wk.	Day wk.
10. Are saggers bone dry when fired?	Not always	Bone dry	Yes	No	Not always	No
11. Do you fire any ware in green saggers? If so, what part of full load?	No	No	No	Yes, 1/2	No	No
12. Give average size, shape and cost of sagger used. (Thickness, sides & bottom)	15″ x 9″ x $5^1/_2$″ Cost 30 c.	16″ x $11^1/_2$″ x $7^3/_4$″ 3/4″ thick Cost —	$17^1/_2$″ x 9″ x $7^1/_2$″ Side 1″ Bottom 7/8″ Cost 50 c.	14″ x $8^1/_2$″ x 6″ Cost —	12″ x 8″ x 6″ 1″ thick Cost —	13″ x 8″ x $5^1/_4$″ Cost —
13. Average weight of ware per sagger?	17 lbs.	28 lbs.	33 lbs.	25 lbs.	30 lbs.	40 lbs.
14. Average number fires sagger lasts?	11 fires	8—Cone 9 7—Cone 12 12—Cone 1	No record	5 fires	6 to 8 fires	5 fires
15. Average % sagger loss?	5%	9%	5 to 7% coal $1^1/_2$ to 2% gas	15%	10 to 15%	20%
16. Sagger body: % Plastic, cost inc. frt.	24% P. $10.35	40% P. $8.50	17% p. $8.00	20% P. $8.00	50% P. $7.00	$33^1/_3$% P. 8.00
% Sandy, cost inc. frt.	28% S. 10.35	20% S. 6.25	33% S. 7.50	30% S. 8.00	0% S. —	$16^2/_3$% S. 8.80
% Grog, cost inc. frt.	48% G. 2.00	40% S. 1.25	50% G. —	50% G. —	50% G. —	50% G. —
17. What % of grog is: Coarse	30% coarse on 10 40% medium	65% coarse	All 10 mesh or over	50% coarse	Not screened	100% coarse
Fine	30% fine	35% fine		50% fine		
Dust	0% dust	No dust				

1. Ware Manufactured?	Wall and Fall Tile					
	1	2	3	4	9	6
18. Do you use any carborundum, alundum, zircon or similar body in saggers?	No	No	No	No	No	No
19. Do you use any sodium silicate in sagger body?	No	No	No	No	No	No
20. Do you use any other materials in sagger body not mentioned? If so, what?	No	No	No	No	No	No
21. What pug mill do you use?	Fate auger brick mach.	Crossley vertical pug	Patterson vertical pug	Horizontal	Vertical	Patterson pug mill
22. Do you pug twice?	No	Yes	Yes	No	Yes	Yes
23. Do you have a special foreman in charge of sagger dept.?	Yes	Yes	No	Yes	No	Yes
24. Have you ever tried using a special shaped grog? If so, will you give us your experience?	No	No	No	Yes—could see no difference	No	No
25. If you had the money and facilities what would you do to improve your saggers?	Have completed improved installation & anticipate desired results	See Note "A"	Use several plastic clays instead only one now used. "See Note B"	See Letter "C"	Will start in near future to use carborundum or some other such material	Use carborundum in sagger body

Note "A"—(1) Build enough pits to temper each mix at least seven days before pugging.
(2) Concrete bins to age mix two weeks after second pugging before pressing.
(3) Storage facilities to weather and age clays six months.

Note "B"—The writer attempted sometime ago to arrive at some theoretical results but was lost in a mass of valueless data, and concluded that practical observation gave better results. You are to be commended upon this endeavor as I believe through a clearing of such information as you request, the most valuable data can be had.

Letter "C"—A factory would be justified in expending any amount of money to enable them to make a better sagger if they knew where and how to spend it. Saggers are the heart and life and are necessary to the profitable operation of any clay plant that uses them, and if out of

1. Ware Manufactured?	1	2	3
2. Kind of kiln?........	Dd. Up Dft.	Rd. D. Dft.	6 Periodic, 1 Dressler tun.
3. Fire to what cone?........	Cone 10	Cone 8	Cone 10 Per. Cone 8 Tun.
4. How long cool?........	64 hrs.	60 hrs.	24 hrs.
5. How make saggers, hand or machine?........	Hand and machine	Machine	Cast in moulds
6. If machine, split or solid ring?........	Split	Split	....
7. Do you level or finish machine made saggers?........	Yes	Yes	....
8. Do you make saggers day, wk., or pc. wk.?........	Day wk.	Day wk.	Day wk.
9. Do you wash saggers day, wk , or pc. wk.?........	Day wk.	Day wk.	Day wk.
10. Are saggers bone dry when fired?........	Yes	No	Yes
11. Do you fire any ware in green saggers? If so, what part of full load?........	No	No	No
12. Give average size, shape and cost of sagger used. (Thickness, sides and bottom)........	18″ x 25″ x 11″ 1″ thick Cost —	Oval, 24″ x 18″ x 3/4″ thick Cost 18 c.	22″ x 18″ x 11″ 7/8″ thick Cost —
13. Average weight of ware per sagger?........	50 lbs.	40 lbs.	40 lbs.
14. Average number fires sagger lasts?........	6 fires	8 fires	15 to 20 fires
15. Average % sagger loss?........	Bis. 25%, Glost 5%	....	....
16. Sagger body: % Plastic, cost inc. frt........	57% P. 12.90	40% P.	25% P. 8.50
% Sandy, cost inc. frt........	43% G. —	60% G.	25% S. 9.00
% Grog, cost inc. frt........			25% G. — 25% Carbor.
17. What % of grog is: Coarse........	On 4 M—35%	Take all	50% coarse
Fine........	Bet. 4 & 7—20 1/2%		50% fine
Dust........	Bet. 7 & 14—14 1/2% Bet. 14 & 32—22% Through 32-8%		
18. Do you use any carborundum, alundum, zircon or similar body in saggers?........	No	No	Carborundum
19. Do you use any sodium silicate in sagger body?........	No.	No	Yes
20. Do you use any other materials in sagger body not mentioned? If so, what?........	No	No	No
21. What pug mill do you use?........	Vertical	Crossley	Raymond
22. Do you pug twice?........	Yes	Yes	Yes
23. Do you have a special foreman in charge of sagger dept.?........	No	No.	No

Ware Manufactured?	Sanitary		
	1	2	3
24. Have you ever tried using a special shaped grog? If so, will you give us your experience?	No	No	No
25. If you had the money and facilities what would you do to improve your saggers?	Not able to secure satisfactory uniformity & quality of clays from shippers	Slop mixing	Do not see much hope of improvement

1. Ware Manufactured?	General Ware			
	1	2	3	4
2. Kind of kiln?	Up Dft.	Down Dft.	D. and Up Dft.	Up Dft. Periodical
3. Fire to what cone?	Cone 9	Cone 8	Cone 9 Bis. Cone 6 Glost	Cone 8
4. How long cool?	48 hrs.	15 hrs. before D. Dft.	3 da. Bis. 2 da. Glost	60 hrs. Bis. 36 hrs. Glost
5. How make saggers, hand or machine?	Hand	Hand & machine	Hand	Pin-hand Common-mach.
6. If machine, split or solid ring?	....	Split	......	Solid
7. Do you level or finish machine made saggers?	......	Yes	......	Yes
8. Do you make saggers day, wk., or pc. wk.?	Pc. wk.	Day wk.	Pc. wk.	Pc. wk.
9. Do you wash saggers day, wk., or pc. wk.?	Pc. wk.	Day wk.	Pc. wk.	Pc. wk.
10. Are saggers bone dry when fired?	Yes	No—but could	Yes	No
11. Do you fire any ware in green saggers? If so, what part of full load?	Yes—1/4 load	Yes—2 spittoons in sag.	Yes—1/4 load	Yes—1/4 load
12. Give average size, shape & cost of sagger used. (Thickness, sides & bottom)	...... Cost —	...... Cost —	...... Cost —	Standard—3/4" thick Cost 80 c.

14. Average number fires sagger lasts?	10 to 12 fires	10 fires	16 fires	12.5 fires
15. Average % sagger loss?	10 to 12%	......	......	8%
16. Sagger body: % Plastic, cost inc. frt.	30% P.	30% P.	28% P.	50% P. 11.00
% Sandy, cost inc. frt.	20% S.	30% S.	18% S.	50% G. —
% Grog, cost inc. frt.	50% G.	40% G.	54% G.	
17. What % of grog is: Coarse	50% coarse	All medium	No data	Coarse, 4 M—10%
Fine	30% fine			10 M—75%
Dust	20% dust			16 M—10%
18. Do you use any carborundum, alundum, zircon or similar body in saggers?	No	No	Experimenting	Some carborundum
19. Do you use any sodium silicate in sagger body?	No	No	No	No
20. Do you use any other materials in sagger body not mentioned? If so, what?	No	No	No	No
21. What pug mill do you use?	Patterson Upright	Upright	Vertical	Patterson
22. Do you pug twice?	Yes	Yes	Yes	Yes
23. Do you have a special foreman in charge of sagger dept.?	No	Yes	No	No
24. Have you ever tried using a special shaped grog? If so, will you give us your experience?	No	No	No	No
25. If you had the money and facilities what would you do to improve your saggers?	......	......	See Letter "D"	Dry saggers, bone dry; size all grog; disintegrate clays; mix in wet pan

Letter "D"—Referring to Question No. 25, the most important improvement to my mind which could be adopted in the average sagger house would be a more accurate and better method of mixing and preparing our clay. We are about to remodel our sagger house and treat our clay in the following manner: All sagger clay will be kept under cover and stored as far as possible when dry. The clay will be mixed as usual in wheelbarrows and afterwards passed through crushers and finely pulverized. From the crusher, the clay will fall into a pit. The grog will be ground on the ordinary grog-panel but instead of its falling as it does now direct on the floor, it will fall on piano wire screen and all of the dirt be extracted. The grog will then fall into a pit similar to the clay. These pits will be located on each side of the horizontal pug mill. Both the clay and the grog will be delivered simultaneously by continuous bucket elevators delivering into the mouth of the pug. The speed of these bucket elevators may be varied to give different proportions of clay and grog. Simultaneously a continuous stream of water regulated to the correct flow will fall into the mouth of the pug. In this manner you will realize that we will get a very much more intimate mixture of clay and grog, and the clay will carry a higher percentage of grog and the consistency of the clay will be uniform. The preparation of the clay will be quicker and cheaper. The present method of putting the clay in pits in more or less lump form and in layers with the grog is, in my opinion, poor and obsolete.

It may interest you to know that in connection with the Watson Stillman sagger machine which we are about to install, we have designed and are having built an automatic machine for punching the pin holes in glost saggers. This, so far as we know, is new and will make the entire operation of sagger making for general ware plants automatic and without skilled labor. Further than this, our plans incorporate an automatic conveying stove in which saggers, which have to be dried out completely and not punched, can be dried well and quickly by the humidity temperature control system. Each sagger will be drawn from the machine on a perfectly straight steel plate which will allow the bottom to dry equally with the sides and also form a level support for the bottom of the sagger.

1. Ware Manufactured?	Vitrified China 1	Vitrified China 2	High Tension Insulators 1	High Tension Insulators 2	Art Pottery 1
2. Kind of kiln?	Up Dft.	Up & D. Dft.	Up Dft.	Up Dft.	Down Dft.
3. Fire to what cone?	Cone 10 Bis. Cone 3 Glost	Cone 11 Bis. Cone N6 Glost	Cone 11	Cone 11	Cone 7
4. How long cool?	$3\frac{1}{2}$ da. Bis. $2\frac{1}{2}$ da. Glost	50 hrs.	36 hrs.	60 hrs.	60 hrs.
5. How make saggers, hand or machine?	Hand & machine	Hand & machine	Machine, steam	Hand & machine	We buy our saggers
6. If machine, split or solid ring?	Solid	Solid	Solid	Solid	......
7. Do you level or finish machine made saggers	Yes	Yes	No	Leveled but not finished	......
8. Do you make saggers day, wk., or pc. wk.?	Mach., da. wk. Hand, pc. wk.	Pc. wk.	Day wk.	Day wk.	......
9. Do you wash saggers day, wk., or pc. wk.?	Day wk.	Day wk.	Day wk.	Day wk.	......
10. Are saggers bone dry when fired?	Not quite	Not always	Yes	Commercially dry	......
11. Do you fire any ware in green saggers? If so, what part of full load?	Yes—$\frac{1}{1}$ load	Yes—20%	Yes—$\frac{1}{2}$ load	Yes—light pcs. around outer edge—$\frac{1}{4}$ ld.	......
12. Give average size, shape & cost of sagger used. (Thickness, sides & bottom)	14″ x 21″ $\frac{3}{4}$″ side $\frac{7}{8}$″ bottom Cost —	Oval—$\frac{7}{8}$″ thick Banjo—13″ x 16″ Cost —	Rd.—14″ dia. Oval—14″ dia. Side $\frac{5}{8}$″ Bottom 1″ Cost $22\frac{1}{2}$ c.	16″ x 8″ high 18″ x 9″ high 18″ Rd. cost 64 c. 16″ Rd. cost 40 c Av. cost 35 c.	18″ rd x 5″ high x $\frac{3}{4}$″ thick Cost 50 c.
13. Average weight of ware per sagger?	......	30 lbs.	$13\frac{1}{2}$ lbs.	13 to 14 lbs.	5 lbs.
14. Average number fires sagger lasts?	Bis. 15 to 20 Glost 5 to 10	8 to 9 fires	6 fires	20 fires	16 fires
15. Average % sagger loss?	Bis. 5 to 10% Glost 10 to 20%	10%	14%	5%	......
16. Sagger body: % Plastic, cost inc. frt. % Sandy, cost inc. frt. % Grog, cost inc. frt.	33% P. — 23% S. — 44% G. —	20% P. — 30% S. — 50% G. —	40% P. 11.00 17% S. 11.00 43% G. —	20% P. 9.83 30% S. 11.87 50% G. 6.50	......

17. What % of grog is: Coarse	All coarse	50% coarse	50% coarse	Do not sift grog	......
Fine		50% fine	50% fine		
Dust		0% dust	0% dust		
18. Do you use any carborundum, alundum, zircon or similar body in saggers?	No	Carbor. 2%	No	No	......
19. Do you use any sodium silicate in sagger body?	No	No	No	No	......
20. Do you use any other materials in sagger body not mentioned? If so, what?	No	No	No	Small amount porc. dust scrap	......
21. What pug mill do you use?	Vertical	Old Type	Patterson	Bonnot Horizontal	......
22. Do you pug twice?	Yes	Yes	Yes	No	......
23. Do you have a special foreman in charge of sagger dept?	No	No	Yes	No	......
24. Have you ever tried using a special shaped grog? If so, will you give us your experience?	No	Jaw crusher better than pan grog	No	No	......
25. If you had the money and facilities what would you do to improve your saggers?	Put clay thru crusher	Fire in special kilns without any filling	See Letter "E"	See Letter "F"	......

LETTER "E"—If sufficient funds were available and production could be maintained while alterations are made, the following method of sagger manufacture would be considered:

It is a well established fact in the re-inforced concrete construction field that the compressive strength of concrete is dependent in no small degree upon the relative proportions of the different sized aggregates in the mix; in other words, assuming the ratio of the cement to the aggregate to be constant, there exists a relation between the amounts of the various sizes of aggregate which will produce the strongest concrete.

With the above fact at hand and believing that there exists an analogy between the concrete and the sagger problems, it would be a plausible idea to dispense with sandy clays and introduce more of the extremely fine grog (finer than 20 mesh). A small batch of sagger mix was made up at this plant using no sandy clay and choosing arbitrarily a relation between the different sizes of grog, the resulting saggers running an average of eleven fires while several lasted thirteen.

In the above experiment nothing but the plastic clay and grog were used and the mix was pugged four times instead of twice.

Such results warrant the installation of a set of screens to size the grog (4, 8, 16 and finer). The grog should be added to the wet pan for mixing with the clay, preventing any grinding by elevating the mullers 3/4" above the bottom of the pan. The remainder of the tempering water should then be added and the entire batch allowed to mix for from five to eight minutes, thus accomplishing or bringing about a uniformity which can not be obtained by six or seven puggings. After one day's ageing, the mix should be in proper condition for pugging out into the bats suitable for the sagger press.

LETTER "F"—We are just putting in operation at Baltimore, a new factory in the equipment of which we were not restricted as to money and facilities. We would install power presses, plenty of large capacity soaking pits, sufficient dry pan equipment, etc., to enable us to make our saggers according to the most approved methods as we understand them. At this plant the grog will be sifted and the dust not used.

1. Ware Manufactured?	?	Grinding Wheels and Abrasives		
	1	1	2	3
2. Kind of kiln?	Down Dft.	Down Dft.	Down Dft.	Semi D. Dft.
3. Fire to what cone?	High enough	Cone 11	Cone 12	Cone 10 to 11
4. How long cool?	72 hrs.	5 days	6 days	7 days
5. How make saggers, hand or machine?	4/5 Mach. 1/5 Hand	Hand	Hand & Machine	Hand
6. If machine, split or solid ring?	Solid	....	Split	....
7. Do you level or finish machine made saggers?	No.	....	No	....
8. Do you make saggers day, wk., or pc. wk.?	Day wk.	Day wk.	Pc. wk.	Day wk.
9. Do you wash saggers day, wk., or pc. wk.?	Day wk.	Do not wash	No	....
10. Are saggers bone dry when fired?	Yes	Not always	Leather hard, not bone dry	Yes
11. Do you fire any ware in green saggers? If so, what part of full load	Full load	None	No	No
12. Give average size, shape and cost of sagger used. (Thickness, sides and bottom)	Oval—7″ high Wall 1″ Bottom 1 1/4″ Cost —	16″ to 20″ O. D. 2 1/2″ deep 1″ wall Cost —	16″ x 4″ Rd. 7/8″ wall & bottom Cost 58 c.	14″ x 6″ Rd. 1 1/4″ thick Unable to get cost
13. Average weight of ware per sagger?	7 lbs.	20″—30 lbs. 16″—18 lbs.	42 lbs.	25 lbs.
14. Average number fires sagger lasts?	Difficult to estimate	8 times	....	50 fires
15. Average % sagger loss?	Less than 2%	12 1/2%	....	....
16. Sagger body: % Plastic, cost inc. frt.	33 1/3% P. 8.00	25% P. 11.33	34% P. 13.00	33 1/3% P. 6.00
% Sandy, cost inc. frt.	33 1/3% S. 8.00	25% S. 10.33	16% S. 12.00	33 1/3% S. 6.00
% Grog, cost inc. frt.	33 1/3% G. 1.25	50% G. —	50% G. —	33 1/3% G. —
17. What % of grog is: Coarse Fine Dust	Not screened	From 4 to 20 mesh; no dust	50% coarse 50% fine 0% dust	Through No. 10 mesh and retained on No. 48 mesh
18. Do you use any carborundum, alundum, zircon or similar body in saggers?	No	No	....	No
19. Do you use any sodium silicate in sagger body?	No	No	No	No

20. Do you use any other materials in sagger body not mentioned? If so, what?	No	No	....	No
21. What pug mill do you use?	Vertical	Patterson	Vertical	Home make
22. Do you pug twice?	Yes	Yes	Yes	No
23. Do you have a special foreman in charge of sagger dept.?	No	Yes	....	No
24. Have you ever tried using a special shaped grog? If so, will you give us your experience?	No	No	....	No
25. If you had the money and facilities what would you do to improve your saggers?	We do not know how our saggers can be improved but we are willing to learn	Improve drying & have them thoroughly dry when fired; make grog of new clays calcined & crushed	....	....

1. Ware Manufactured?	Electric		Porcelain	
	1	2	3	4
2. Kind of kiln?	D. Dft. Didier March tunnel	Up Dft.	Combination Up & D. Dft.	14′ Up Dft.
3. Fire to what cone?	Cone 11	Cone 12	Cone 12	Cone 10
4. How long cool?	50 hrs.	22 hrs.	48 hrs.	72 hrs.
5. How make saggers, hand or machine?	Machine	Machine	Machine	Crossley hand power machine
6. If machine, split or solid ring?	Solid	Split	Solid	Split
7. Do you level or finish machine made saggers?	No	Yes	No	No
8. Do you make saggers day, wk., or pc. wk.?	Pc. wk.	Pc. wk.	Pc. wk.	Pc. wk.
9. Do you wash saggers day, wk., or pc. wk.?	....	Pc. wk.	Day wk.	Day wk.
10. Are saggers bone dry when fired?	No	Not always	Yes	No
11. Do you fire any ware in green saggers? If so, what part of full load?	Yes—1/2 load	Yes—1/2 load	No	Yes—50% load
12. Give average size, shape and cost of sagger used. (Thickness, sides & bottom)	12″ x 6″ Rd. 1″ thick Cost 30 c.	12″ x 4″ Rd. 1″ thick Cost 30 c.	12″ x 5 1/2″ Rd. Top & side 3/4″ Bottom 1″ Cost 30 c	13″ x 16″ Oval 1″ sides 1 1/4″ bottom Cost 32 c.

1. Ware Manufactured?	Electric		Porcelain	
	1	2	3	4
13 Average weight of ware per sagger?	20 lbs.	10 lbs.	20 lbs.	60 lbs.
14. Average number fires sagger lasts?	7 fires	6 fires	15 fires	10 fires
15 Average % sagger loss?	14%	$13^3/_4$%	7%	9%
16 Sagger body: % Plastic, cost inc. frt.	30% P. 9.25	48% P. 8.00	30% P. 14.50	40% P. 10.83
% Sandy, cost inc. frt.	40% S. 10.42	S. —	30% S. 11.50	20% S. 5.85
% Grog, cost inc. frt.	30% G. —	52% G. 3.00	40% G. —	40% G. —
17. What % of grog is: Coarse	Coarse 80%	Coarse 64%	All that passes $^1/_2$" and held on 8 mesh; no dust or fine	Grog screen $^1/_4$" max. and $^1/_{16}$" min.
Fine	Fine 20%	Fine 31%		
Dust	Dust 0%	Dust 5%		
18. Do you use any carborundum, alundum, zircon or similar body in saggers?	No	No	No	No
19. Do you use any sodium silicate in sagger body?	No	No	No	No
20. Do you use any other materials in sagger body not mentioned? If so, what?	No	No	No	No
21. What pug mill do you use?	Crossley 24"	Logan Vertical	Patterson	Crossley Horizontal
22. Do you pug twice?	No—first mix body in wet pan	Yes	Yes	Yes
23. Do you have a special foreman in charge of sagger dept.?	Yes	No	No	No
24. Have you ever tried using a special shaped grog? If so, will you gives us your experience?	No	No	No	No
25. If you had the money and facilities what would you do to improve your saggers?	Experimenting with various clays. No definite results to reports	See Note "G"	....	Would try wet pan

Note "G"—Would have pug mill to pug a uniform bar of clay so as to have no cracks for the oil from the sagger die to get in and have a chance to weaken the sagger in drying or firing.

Would then equip sagger shop with a high powered solid case sagger machine to do away with any chance for a feed away of clay.

Would then have the saggers hand finished or leveled before going to the dryer.

Why should a peppering with a material having a low coefficient of expansion, more or less surrounded by a material with a fairly high coefficient of expansion, give these results? See sample.

No. 7. A sagger is a good deal like a high tension insulator; *i.e.*, the preparation and manipulation of the clay—the final finishing together with careful handling and drying—is 50 per cent of the battle for good ware. Therefore, may we not suggest that the potter will take more care with a body which contains carborundum and costs four times as much as the regular sagger body.

No. 8. We have been led to expect longer life from saggers fired in continuous kilns. Yet we show 50 fires in one case, 15 to 20 in another, and only 7 in a third. Can the continuous kiln men give us light on this?

No. 9. From the chart we have made a rough analysis and average of the number of fires shown at the different cones:

Cone 1	12 fires	
Cone 7	16 fires	
Cone 8	10 fires	
Cone 9	11 fires	
Cone 10	19 fires	(This is high due to one report which shows 50 fires at Cone 10 and cooled 168 hrs. This is not a continuous kiln.)
Cone 11	8 fires	
Cone 12	9 fires	
Cone 17	50 fires	(This is a continuous kiln.)

We have also made an analysis giving the average number of fires based on the hours cooling:

24 hrs.	20 fires	(This is high due to one report showing 50 fires at cone 17 in a continuous kiln.)
36 hrs.	6 fires	
48 hrs.	10 fires	
50 hrs.	7 fires	
60 hrs.	11 fires	
72 hrs.	7 fires	
120 hrs.	9 fires	
168 hrs.	50 fires	(This is not a continuous kiln.)

No. 10. Cost of sagger body containing 30 per cent carborundum:

48% Plastic at $8.00 per T.	$ 3.84	
22% Grog at $2.00 per T.	0.44	
30% Carborundum at $60.00 per T.	18.00	
100%	$22.28	cost per T.
Less reclaimed broken saggars	1.50	
	$20.78	net cost per T.

Cost of sagger body without carborundum:

48% Plastic at $8.00 per T.	$3.84	
52% Grog at $2.00 per T.	1.04	
100%	$4.88	cost per T.
Less reclaimed broken saggars	1.50	
	$3.38	net cost per T.

Based on the above figures we will try to show the difference in cost of 100 saggars that last 21 fires, containing carborundum, and 300 saggers lasting 7 fires each, containing no carborundum.

100 carb. sag. at 30 lbs. ea. = 3000 lbs. at $20.78 per T.	$31.17
100 carb. sag. (make, hdle. and wash)	6.47
100 carb. sag. (cost 1/2 load profit on same at 5 c. per sag.)	5.00
	$42.64

Total cost of 100 saggers containing 30 cer cent carborundum, and lasting 21 fires is $42.64.

300 sag. (no carb.) at 30 lbs. ea. = 9000 lbs. at $3.38 per T.	$15.21
300 sag. (no carb.) (make, hdle. and wash)	19.41
300 sag. (no carb.) (cost 1/2 ld. profit on same at 5 c. per sag.)	15.00
	$49.62

Total cost of 300 saggars, containing no carborundum, and lasting 21 fires is $49.62.

Based on the above figures it would be reasonable to assume that if room, efficiency, machine wear and tare be taken into consideration, 20 fires in a 30 per cent carborundum sagger would be an economy. When the grog begins to return containing carborundum still better results would be expected.

NOTE ON THE ACID RESISTANCE OF ENAMELED COOKING UTENSILS[1]

By B. T. Sweely

ABSTRACT

Apparent segregation of the constituents of an enamel under the influence of gravitation.—Experiments with trial pieces with poured samples, and with enameled ware of various mfgr's. showed that the surface of the layer of enamel which is uppermost during firing and cooling is readily attacked by acid, thus indicating, apparently, that the more soluble materials tend to rise to the top of the melt. It is therefore recommended that enameled kitchen utensils be fired in an inverted position. In the discussion by Bryan A. Rice a series of similar experiments are described using small shallow cups. Quantitative tests failed to show any difference in acid resistance and it is suggested that the author's results were due to the nature of the gases in contact with the enamel surface or to *volatilization*. In his reply the author accepts this explanation of his results.

During the development of a number of sheet steel enamels for various purposes, the writer experienced no little difficulty with inconsistent results when the enamels were applied to trials and tested for acid resistance. The test used was the application of a few drops of a ten per cent solution of citric acid[2] to the surface of the ware, allowing it to remain for ten minutes, then washing and wiping dry and noting its effect on the lustre of the enamel.

Under this test, the same enamel would frequently show widely different results, sometimes being only slightly affected, the gloss not being impaired beyond showing a slight iridescence, while in other cases the lustre was completely destroyed, a chalky white surface resulting. Both results were not encountered on the same surface but seemed to vary from piece to piece.

Attempting to get some explanation for this peculiar phenomena, a number of trial batches of various composition were melted in a small crucible and the enamels poured onto an iron slab to secure a surface for testing with the acid without the necessity of

[1] Received March 1, 1921.

[2] This Journal, 3, 560 (1920).

making up enamel trials. The results were rather surprising in that it was found that the upper surface alone was attacked by the acid, the side next to the metal slab and all fractured surfaces being apparently wholly unaffected by the acid treatment. Pieces with fractured lower and upper surfaces were immersed in the acid solution for thirty-six hours, boiled gently for two hours, with exactly the same results, *i. e.*, the upper surface was distinctly chalked while the fractured surfaces and the surface next to the metal slab showed no evidence of attack. Repeated experiments checked this in every case, except in those enamels whose acid resistance was sufficiently high to be unaffected under any conditions by a solution of this strength and activity.

It seemed, therefore, that in the case of these trials, there was a segregation of the more soluble constituents of the enamel on the upper surface and if this could be eliminated from the surface of the enamel on the inside of a cooking utensil, the acid resistance of ware made from such an enamel would be materially improved. A number of trials were therefore made up from a formula which exhibited this phenomenon and fired upside down in the final fire. Under this condition, if this same phenomenon took place in the vessel as occurred when the glass was poured on a slab, the inside bottom of the vessel should present a surface similar to the under-surface of the glass poured on the slab and result in a better acid resisting cooking utensil than could be secured by firing in an upright position.

The results were exactly as expected, the inside bottom surfaces of the pieces fired as described above being unaffected by the acid test while the outside of the same piece was readily etched. Further trials of various enamels checked this in every instance, the ware fired upside down having a better acid resistance on the inside than on the outside in every case, and was with nearly every enamel tried wholly unaffected by a ten per cent solution of citric acid, however long the exposure. Many of these pieces were filled with the acid solution and set in another vessel containing the same acid solution, and allowed to remain for thirty-six to forty-eight hours, the result being that the outside was often distinctly chalked while the lustre of the inside was apparently unaffected. The same test was applied to the wares

of a number of different manufacturers which had obviously been fired in an inverted position in the last fire, and the same result was observed, which would seem to indicate that the results secured were not peculiar to the particular type of enamel used by the writer in this work. I regret that it is not possible to present the formulae of the enamels tested, but from the results secured, I believe anyone can duplicate this work on an ordinary sheet steel enamel unless it is much more resistant to organic acids than is usually the case.

The application of the above observations is obvious, the manufacturer need only plan to fire all cooking utensils in an inverted position in the final fire to insure a decided improvement in the acid resistance of any enamel and in most cases to render it sufficiently acid resistant to be proof against attack by the most active acid encountered in kitchen use.

CERAMIC LABORATORIES
COONLEY MANUFACTURING COMPANY
CICERO, ILLINOIS

Discussion

By BRYAN A. RICE: In an attempt to check the results obtained by Mr. Sweely, the following experiments were conducted.

Test pieces were prepared by taking our standard 3″ diameter laboratory test cups and cutting down the sides until only the bottom remained. This gave practically a flat surface, yet it had sufficient depth to hold a few cc. of acid. A cup or test piece of this type was desired because with a deep dish in an inverted position the composition and nature of the gases in contact with the enameled surface might be entirely different from that in contact with the outside of the dish due to chemical reactions taking place during burning or to volatilization of certain enamel constituents. The shape of the piece might not allow the same circulation of these gases when burned in the inverted positions as when burned upright. With a flat shape practically the same conditions would prevail above and below the piece. Twenty of these were used. Each was stenciled and then cleaned by sand blast after having been heated to red heat to drive off oil and grease.

The pieces were then sprayed with a ground coat and burned in

a small electric muffle furnace where the temperature could be easily controlled and an oxidizing atmosphere maintained. Numbers 1 to 10, inclusive, were burned in an upright position. Numbers 11 to 20 were inverted. Each piece was given the same length of time in burning at a constant temperature.

Two types of cover coats were used. One, which we will call Enamel "A," is used almost exclusively for dairy purpose and is only fairly resistant to organic acids. The other, Enamel "B," is unattacked by organic acids and is also used for dilute inorganic acids.

The number of applications of these cover coats varied, as will be shown in the table which follows. All first coats of Enamel "A" were burned the same length of time at the same temperature both for those in the upright position and those which were inverted. The same was true of Enamel "B." Likewise constant burning conditions prevailed for each successive coat.

After burning all trials were carefully weighed. 10 cc. of 10 per cent Citric Acid was placed in each dish enameled with Enamel "A." 10 cc. of 1.5 per cent Hydrochloric Acid was used for those enameled with enamel "B." This amount of acid left only a small portion of the enameled surface exposed. They were allowed to stand twenty-four hours. They were then washed, dried and weighed again.

With those enameled with "A" very little difference could be noted between the ones burned in an upright position and those which were inverted. That is, the three-coat pieces of the former checked the three-coat pieces of the latter well within limits of error since the total weight of the trials averaged 120 grams. The same is true of the four-coat pieces, while the five-coat trials checked fairly well, considering the fact that there was only one of each.

The results obtained with enamel "B" were unsatisfactory, since they were not consistent within themselves. While the averages checked in a surprising way, the data can not be considered of much value. For example, in the third coat trials burned in the inverted positions the difference in loss was greater than the loss in weight of one of the trials. The only explanation the writer has is that the acid used was too weak and the resulting losses so

small that a slight irregularity anywhere along the line during processing or subsequent treatment caused a relatively large variation in the final results.

When the trials were observed by eye all showed visible etching, but nothing was noted which did not check in with the gravimetric results.

From the above tests it would seem that the results obtained by Mr. Sweely might be due more to the nature of the gases in contact with the enamel surface or the degree of volatilization taking place, than to the segregation of the soluble constituents.

It would be interesting to hear from Mr. Sweely as to whether he found that the bottom of a piece burned in the upright position had the same resistance on the inside as the outside of the bottom of a piece burned inverted.

RESEARCH LABORATORIES
ELYRIA ENAMELED PRODUCTS CO.
ELYRIA, OHIO

AUTHOR'S CLOSURE: Mr. Rice has shown by careful experiment that the assumption that the phenomena described in the above mentioned paper was due to segregation, is open to question. After listening to Mr. Rice's discussion of this paper, further experimental work has confirmed his results in that it was found that there was no difference in the acid resistance of the top and bottom surfaces of shallow or flat ware fired in an inverted position. This point was brought out by the writer during the discussion of the paper on the floor of the division.

The acid test used by the writer in this work was entirely qualitative, no attempt at quantitative determinations being made. A quantitative test, similar to that used by Mr. Rice, on ware which showed a decided difference in its acid resistance under the qualitative test, would be of considerable interest, and the writer hopes to secure such data for presentation in the near future.

Mr. Rice's conclusion that the results secured by the writer "may be due more to the nature of the gases in contact with the enamel surface or the degree of volatilization taking place, than to the segregation of the soluble constituents," is in harmony with all the writer's observations, both on glass and finished ware, inasmuch as it is on deep shapes in which the gases volatil-

ized would be confined when fired in an inverted position that the difference in apparent acid resistance between inside and outside of the shape is most pronounced.

Regarding Mr. Rice's question "as to whether the bottom of a piece burned in an upright position has the same resistance on the inside as the outside of the bottom of a piece burned inverted," would say, I have found this to be the case insofar as the qualitative test would determine.

CORRECTION

Elutriation Tests on American Kaolins, by H. G. Schurecht. THIS JOURNAL **3**, 359 (1920), Line 9, and 17, for V 0.636 read $V^{0.636}$.

CERAMIC ABSTRACTS*

Author Index to Abstracts for May

* The abbreviation (C. A.) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. **What a "cost system" should do for you.** ANON. *Special Rep.*, U. S. Chamber of Commerce, Fabricated Production Department.—The importance of cost accounting is discussed under the heads: Purpose and value; insurance of profits; business control; increased prod.; variations from stand. practice; control of overhead; intelligent competition; unprofitable lines; investment; and general. This and other pamphlets on the same subject will be sent on request addressed to Fabricated Prod. Dept., U. S. Chamber of Comm., Mills Bldg., Washington, D. C. ED.

2. **Recent developments in spray painting.** HENRY A. GARDNER. Paint Mfrs. Assoc. of U. S., *Circ.* **114**, 18 pp., Jan. 1921.—A review is given of the adaptability of spray painting to general use on interior and exterior surfaces of large area. This type of paint application will increase rather than diminish the amt. of work the master painter is called on to do, on account of the greater amt. of painting which will be stimulated by lower labor costs per job. Spray coats have been found equal to brush coats in durability. Portable spraying outfits, photomicrographs of sprayed films, etc., are illustd.
F. A. WERTZ. (*C. A.*)

PATENT

3. **Method of kiln setting and burning.** GRAFTON E. LUCE. U. S. 1,369,752, Feb. 22, 1921. A method of setting a kiln which consists in dividing it into a plurality of horizontal portions adapted to be burned successively, the dividing means having provision for automatically changing as the burning progresses. C. M. SAEGER, JR.

Apparatus and Instruments

4. **Microscopy with ultraviolet light.** J. E. BARNARD. *Nature*, **106**, 378–81 (1920).—A review. W. H. ROSS. (*C. A.*)

5. **A new micro combustion furnace for the determination of carbon, hydrogen and nitrogen.** W. DAUTWITZ. Zürich. *Chem. Ztg.* **44**, 963 (1920).—Description, with 2 poor cuts, of a furnace which, with absorbers attached, may be clamped to a table. J. H. MOORE. (*C. A.*)

6. **Effect of humidity on leather belting.** F. W. ROYS. Worcester Polytechnic Inst. *Textile World J.*, **59**, 201–5 (1921).—Stretch of belting is greater for a given change in tension at high humidity than at low with a const. temp., for given change in humidity at const. temp. is greater at high tensions than at low, and is greater for given change in humidity at high temp. than at low. Curves are given. CHAS. E. MULLIN. (*C. A.*)

7. **Pyrometric practice.** PAUL D. FOOTE, C. O. FAIRCHILD AND T. R. HARRISON. Bur. Standards, *Tech. Paper* No. **170**.—The primary object of this volume is evidently to present information which is useful in the choice and operation of pyrometric installations. Enough of the underlying theory has been included to make the principle of operation of each type of instru-

ment readily understood. Special stress is laid upon refinements of construction and installation and precautions for operation. Indicating and recording instruments operated by bimetallic springs or the differential expansion of graphite and metal are considered. Several types of thermocouples are described suited to different ranges of temp. and conditions of use. The method of connecting several thermocouples to a common return wire is subject to large errors, and its use is seldom or never justified. Many wiring diagrams of typical installations are shown. Several designs of resistance pyrometers are described, as are different methods of connecting to the bulb for the purpose of minimizing or eliminating errors due to lead resistance and to resistance at dial contacts within the instrument. The leading recording instruments are shown in cuts and described in detail in the chapter on recording pyrometry. Transformation-point indicators and recorders are treated at some length, along with different methods of interpreting the data. Discussion of the control of processes through a knowledge of the temps. involved is not confined to a description of the apparatus used but enters into the broader phases of the subject. The subject of melting-point methods is treated at length. The general classes of substances considered under this heading are metals, alloys, salts, and *refractory materials*, and for the temperature measurements, thermoelectric resistance, and optical pyrometers are discussed. Where substances of known melting points are employed, the methods are equally applicable to the calibration of the pyrometers being used. Tables of melting points are given. Detailed information is presented as to the most suitable type of pyrometer to be used, the proper crucible and atmosphere for many materials, and suitable furnaces for different classes of work. Complete information is given for the calibration of all of the important high-temp. measuring instruments which are used industrially, and suitable app. and accessories are described for each type of calibration. The method for welding thermocouple junctions, the method of calculation of cold-junction corrections, and methods of procedure to avoid errors in the use of cold-junction compensators are considered in detail. In the section on ind. applications of pyrometry no attempt is made to give all the applications. Some of the applications which offer peculiar difficulties are considered. In this connection are treated the applications of pyrometry to *glass manufacture, glass annealing, rotary portland cement kilns, ceramic processes*, coke manufacture, and steel manufacture. In an appendix are given conversion tables from Fahrenheit to Centigrade and vice versa, and other useful data. H. F. S.

8. A simple portable instrument for the absolute measurement of reflection and transmission factors. A. H. TAYLOR. Bur. of Standards, *Sci. Paper* No. 405.—The reflectometer is a sphere with a small segment cut away, leaving a hole over which the surface to be tested is placed. The wall of the sphere is viewed through a small hole by means of a portable photometer, the spot viewed being screened from the test surface. A lighting tube, set at an angle to the sphere surface, is arranged to rotate about an axis normal

to the surface of the sphere, so that the direct light can be thrown on the test surface or on the sphere wall. The theory of the integrating sphere shows that the reflection factor of the test surface is simply the ratio of the photometer readings in the two cases, no assumption being made as to the way in which the light is reflected from the test surface. Moreover, the reflection factor measured is not affected by selective reflection by the sphere walls. No accurate voltage adjustment of the lamps in the photometer and the reflectometer is necessary, as both operate from the same battery. The use of a low-voltage flashlight lamp in the lighting tube makes the instrument very portable and convenient. By the addition of an exterior light source the same instrument can be used to measure transmission factors of clear or diffusing media. H. F. S.

See also Abstr. Nos. 42, 64.

Refractories and Furnaces

9. **Laboratory melting furnace with electrical heating.** HANS HECHT. *Chem.-Ztg.*, **44**, 956 (1920).—A vertical alundum tube furnace with a resistor of powdered carbon and a vertically adjustable table for supporting the 600-cc. crucible. The crucible may be tapped, in place, if desired, the charge flowing out through the hollow supporting column of the table. 150 A. at a 110 V. gives temps. up to 1700°C. ED.

See also *Keram Rundschau*, **29**, 69-70 (1921).

10. **The industrial use of pulverized fuels.** H. DROUOT. *Technique moderne*, **12**, 407–17, 476–9 (1920).—A review of the merits of pulverized coal, of the various systems devized for handling and feeding it (Holbeck, Quigley, Fuller, Bergman, Covert, Aéro, Stroud, Lopulco), and of the various uses to which it has been put (stationary boilers, waste-heat boilers, locomotives, metallurgical furnaces of all kinds, blast furnaces, roasting of Fe ores, marine boilers, and internal-combustion engines), together with a brief mention of pulverized lignite and pitch, and colloidal fuel. A. P.-C. (*C. A.*)

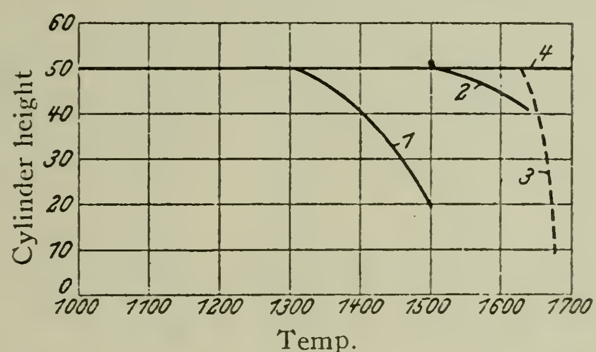
11. **Grindle system of burning powdered coal.** ANON. *Iron Age*, **106**, 1614–5 (1920); cf. *Ibid.*, **104**, 444 (1919).—New features of the Grindle system, including conveying and control, are described. J. L. W. (*C. A.*)

12. **Pulverized coal an effective means of fuel economy.** ANON. *Elec. Rev.* (*Chicago*), **78**, 134 (1921).—A review. Fuels not available for other uses may be burned effectively in powdered form. Vast resources in low-grade coals become available. C. G. F. (*C. A.*)

13. **Colloidal fuels, their preparation and properties.** S. E. SHEPPARD. Research Laboratory, Eastman Kodak Co., Rochester, N. Y. *J. Ind. Eng. Chem.*, **13**, 37–47 (1921); cf. *C. A.*, **14**, 1026, 1027, 2406, 3313–4.—The article comprizes a discussion of colloids and of the properties of colloidal fuel, essentially, as far as that fuel is concerned, the material covered by the abstracts cited. ARTHUR G. WILLIAMS. (*C A.*)

14. The case for colloidal fuel. LINDON W. BATES. *Chem. Age (London)*, **3**, 558–9 (1920); cf. *C. A.*, **14**, 1026, 1027, 2406, 3313–4, and the preceding abstract.—The subject matter of this article is covered by the abstracts cited. ARTHUR G. WILLIAMS. (*C. A.*)

15. The behavior of refractory brick under load at high temperatures. K. ENDELL. Berlin. *Z. Stahl u. Eisen*, No. **1** (1920).—An eye-beam 4-m. long was employed as a lever arm to apply a load of 1 kg. per sq. cm. to a refractory cylinder 5 cm. diam. and 5 cm. high, the pressure being applied by a hard carbon rod. A pointer moving over a scale indicated expansion,



contraction and deformation. A carbon resistance furnace with a free working space 12 cm. in diam. was employed. Temps. were determined to ±10° with a Holborn-Kurlbaum op. pyrom. sighted through an opening in the side of the furnace. The *results* are shown in the table and figure.

BEHAVIOR OF VARIOUS REFRACTORIES UNDER LOADS OF 1 KG. PER SQ. CM. AT HIGH TEMPERATURES

Material	Melting point ° C.	Max. furnace temp. ° C.	Deformation temp. ° C.	Deformation Mm.	Heating time Total	Heating time Above 900°	Remarks
Fire-clay	1730	1500	1300	30	4h 30′	3h	The cylinder exhibits lateral expansion due to homogeneous deformation.
Magnesite	>2000	1650	1500	10	4h 45′	3h 30′	Circular fracture with little deformation.
Silica brick	1750	1680	1650	broken	4h 10′	2h 50′	The compression takes place in jumps, the broken pieces showing little deformation.

Carbon brick > 2000	1720	No deformation	4h 55′	3h 25′	No deformation but 4% shrinkage due to loss of carbon and bond from combustion and volatilization.

Ed.

16. Refractories for electric furnace. R. M. Howe. *Chem. Met. Eng.*, **23**, 1215–8 (1920).

Material	Fusion Point ° C.	* Point of failure under 50 lbs./sq. in. load, ° C.	Thermal Conductivity at 1000° C.	Specific heat at 100° C.	Resistance to spalling
Fire-clay	1700	1350–1400	0.0039	0.199	good[3]
Silica	1700	1600[1]	.0044	.219	poor[3]
Magnesia	2165	1480	.0079	.231	poor[3]
Chrome	2050	1425	.0057	...	poor[3]
Bauxite	1785	1350 or more	Same as fire-clay	...	good[3]
Zirconia	2575	1510[2]	low[3]	...	...
Carborundum	2240	above 1650	.0231	.186	good[3]
Alundum	2050	above 1550	high[3]	.198[1]	good[3]

* A pressure of 25 lbs. per sq. in. is usually applied at present in making these tests.

[1] Estimated from known data.

[2] Average of results with 25 lbs. and 75 lbs. per sq. in.

[3] Private communication.

Refractories should be laid up with a material similar to the brick themselves, or one which will not corrode or flux them, using as small a joint as possible. The furnace should be constructed so that heat will be conducted away from the hotter portions, using water cooling if necessary. The ratio of heating to cooling area should be made as low as possible. Refractory brick or shapes should be heated from one side only in order to keep the heating surface low and in order to avoid the effectof pressure at high temperatures. Insulation lowers the margin of safety and should, therefore, be avoided, even to the extent of not allowing dust to accumulate on the roof. Heating of the furnace should be done gradually, especially where magnesite and silica brick are involved. When the furnace is being cooled it should be remembered that cold blasts produce or accelerate spalling. H. F. S.

17. Moore rapid "Lectromelt" furnace. R. D. Thomas. *J. Am. Inst. Elec. Eng.*, **39**, 1038–9 (1920).—The special features of the Moore furnace are: Melting is very rapid, $^1/_2$ to $^3/_4$ hr. per charge, roofs have long life, av. 200 heats; power consumption is low, 350 kw. hr. per ton, the *inverted dome bottom holds refractories in place,* no mechanism in pit; conducting arms also support

electrodes, thereby lessening deterioration. It is claimed that this furnace has doubled the daily output of the av. elec. furnace of the same capacity.

O. A. HOUGEN. (*C. A.*)

18. High-grade talc for gas burners. J. S. DILLER, J. G. FAIRCHILD AND E. S. LARSEN. *Econ. Geol.*, **15**, 665–73 (1920).—The production and imports of talc for the purpose mentioned are briefly discussed. The talc thus used is usually found in metamorphic limestone and in some instances in altered basic igneous rocks. Domestic deposits at Hewitts, N. C., and in Harford County, Md., and foreign deposits in Germany, France, Italy and India are described. Chem. analyses are given for material from each locality. Microscopic examn. shows chlorite to be the most abundant associate, usually from 3 to 15%. Compn. is the most important factor in detg. its suitability for gas tips. Fineness and uniformity of texture follow in importance. In these the German talc excels others; it is the product of chem. action during contact metamorphism, and no similar deposits are known in the U. S.

A. B. PECK. (*C. A.*)

19. An improved air heater. F. J. W. BELTON. *Chem. Trade J.*, **67**, 646 (1920).—An app. comprizing a number of similar parts or sections built side by side, and one upon another, and placed between end sections containing air transfer passages, and the inlet and outlet between sideplates. Air enters at the top, passing in streams at high velocity back and forth in horizontal channels, meeting the products of combustion from the gas burners which rise through narrow vertical ducts between several air channels, while suitable horizontal ribs project into the vertical ducts thereby giving the gases a circuitous path. Each vertical section is a portion of two air-heating channels at each side of the portion of gas duct. The structure is held as a unit by bolts clasping the flanges upon the end and side sections. The projecting edges form a good joint with the parts of the sections which seat therearound preventing products of combustion gaining access to the air space of the heater. The gas burners which extend the width of the app. may be high- or low-pressure type. An exptl. run gave a thermal efficiency of 87.5%.

W. H. BOYNTON. (*C. A.*)

20. Core-baking ovens electrically heated. J. L. JONES. *Elec. Rev.*, **78**, 132–4 (1921); cf. *C. A.*, **15**, 46.—A new thermostat consists of a strip of porous refractory material impregnated with a material, nonconducting up to a given temp. but conducting above it. The strip is supported by Ag terminals and connected to a suitable relay, motor-driven switch and a small transformer. The impregnating Material (not divulged) regulates the temp. required for core-oven work and is capable of controlling temps. from 65° to 800°. The wt. of core plates should be reduced to a minimum consistent with stiffness. Tables show percentages of various ingredients in core materials and the strength of cores made under various conditions in electrically heated ovens. (*C. A.*)

PATENTS

21. Glass pot furnace. MAURICE MATHY. Leige, Belgium. U. S. 1,369,453, Feb. 22, 1921. A crucible glass furnace or oven comprising a plurality of separate crucible chambers, the bottom of each chamber being formed with cavities, a crucible in each chamber, fragments of porous refractory material surrounding the crucible and filling the cavities, gas and air supply ducts at the basis of the cavities, a regenerator for each chamber for effecting the heating of the air for combustion, a number of glass-holes, a duct connecting each of the glass-holes with the air supply duct of the chambers, and fusible closing means in the connecting ducts.

22. Tunnel-kiln and method of operating of same. PHILIP H. DRESSLER. U. S. 1,369,330, Feb. 22, 1921.—The method of operating a tunnel-kiln which consists in maintaining an atmosphere formed by a hot body of gaseous material in a central portion of the kiln chamber without substantial movement of the atmosphere except for convection current circulation thereof and blowing gaseous material into the end of the kiln along the top of the kiln chamber so as to create a downward flow of the kiln atmosphere between the end and center of the kiln with a return flow along the bottom of the kiln toward the kiln end, and the escape therefrom of the excess gaseous material passed into the kiln chamber whereby the maintenance of an unduly high top temperature in the end of the kiln by reason of the convection current circulation of the kiln atmosphere is prevented,

23. Tunnel-Kiln. PHILIP D'H. DRESSLER. U. S. 1,366,369, Jan. 25, 1921. A tunnel kiln having an elongated kiln chamber comprising a heating zone and a goods cooling zone at one end of the heating zone, and having an air preheating and goods cooling conduit extending along the cooling zone, and a combustion chamber separated by a heat conducting wall from the kiln chamber extending along the heating zone thereof, the improvement which consists in a fan or blower having its inlet connected to the cooling zone conduit and its outlet connected to the combustion chamber whereby pressure differentials tending to create leakage flow between the kiln chamber and the combustion chambers or conduit may be minimized.

24. Tunnel-kiln. ARTHUR T. SHEPARD. U. S. 1,366,424, Jan. 25, 1921. A tunnel kiln with longitudinally extending masonry benches at the sides of a pathway at the bottom of the kiln for goods carrying means and having mounted on each of the benches an elongated combustion chamber, pipes connected to and forming an extension of the combustion chamber, and a header to which the ends of the pipes remote from the combustion chamber are connected, each bench being formed with a channel having uprising end portions which communicate one with the interior of the header and the other with the interior of the combustion chamber at the opposite ends of the pipes and with an outlet from the channel for products of combustion, and dampers regulating the relative amounts of products of combustion passing from the

combustion chamber to the outlet through the pipes and a portion of the channel, and through the by-paths about the pipes formed by the remaining portion of the channel. C. M. SAEGER, JR.

25. Furnaces. H. STRACHE. Brit. 152,668, Oct. 19, 1920. A process and app. for the combustion of fuel in furnaces with the recovery of by-products consists in supplying the fuel to the furnace through one or more pipes, chambers or passages in which the fuel is coked and gasified by the heat from the furnace, the coke being fed onto the furnace grate and the gases withdrawn from the coking chambers mixed, if desired, with combustion products and delivered to app. for sepg. the by-products, the residual gases being returned to the furnace. A suitable app. is specified. (*C. A.*)

See also abstract Nos. 39, 41, 76; also Book Reviews.

Chemistry, Physics and Geology of Raw Materials

26. On the transformation of quartz into tridimite. O. REBUFFAT. *Chem. Zentr.*, **23**, 643 (1920); *Giorn. die Chin. ind. ed appl.*, **2**, 437–8 (Aug. 1920).—Observation of the behavior of silica brick when burned seems to indicate that the presence of small amts. of P_2O_5 favors the formation of tridimite.

WM. M. CLARK.

27. Swelling phenomena in fibrous alumina. HEINZ V. ZEHMEN. *Kolloid-Z.*, **27**, 233–5 (1920).—Both the "fibrous alumina" (H. Wislicenus, *Z. angew. Chem.*, **17**, 805 (1904)) as prepared by E. Merck, and the so-called "sprouted alumina" (*C. A.*, **1**, 2038) which is ignited and therefore converted into Al_2O_3 and freed from Hg, behave like reversible gels, resembling the gels of SiO_2 and ZrO_2 (studied especially by van Bemmelen) in their adsorption and loss of water. Dehydration between 100 and 200° proceeds gradually, each temp. corresponding to a certain water content. The Merck prepn. loses 6.5% at 100°, a further 3% at 150°, and 2–3% at 200°. On exposure to the air this mosture is regained to within about 1% (hysteresis), 10% within one day and the rest after 5–6 days. After several weeks in an atm. satd. with H_2O vapor, the water adsorption may equal 60%. The swollen fibrous *clay* shows a marked increase in vol. and adsorbs much more Congo red than would be expected from its Al_2O_3 content, in some cases over double, which seems to be due to the increase in the active internal surface accompanying dispersion. JEROME ALEXANDER. (*C. A.*)

28. Note on crucibles used in rock analysis. HENRY S. WASHINGTON. *J. Wash. Acad. Sci.*, **11**, 9–13 (1921).—For Na_2CO_3 fusions a crucible made of Pt-Ir has proved more satisfactory than one of pure Pt because it is less liable to indentation and susceptible of a higher polish, so that fused cakes are easier to remove. For several mos. a Pd-Au crucible has been used for these fusions and has proved even more satisfactory. The av. loss in wt. after each Na_2CO_3 fusion is about 0.2 mg. or only about half as much as with a Pt-Ir crucible. W. T. H. (*C. A.*)

29. **Survey of the physics and chemistry of colloids.** THE SVEDBERG. *Chem. Met. Eng.*, **24**, 23–7 (1921).—A review. JEROME ALEXANDER. (*C. A.*)

30. **New method for the determination of potassium in silicates.** JEROME J. MORGAN. Columbia Univ., New York. *J. Ind. Eng. Chem.*, **13**, 225–7 (1921).—Digest 0.3–0.6 g. of the silicate with excess of HF, evap. to dryness, add 25 cc. 3 N HCl and warm until all except small amt. of CaF_2 dissolves. Add 10 cc. of 10% $HClO_4$ and evap. to dense white fumes and finally (on a special low temp. elec. heated sand bath) to dryness. Take up residue with hot water, add 1 to 2 cc. of the 10% $HClO_4$ and repeat the above evaporation as many times as may be necessary to give a residue completely soluble in hot water. The residue from the final evap. is allowed to cool, 20 cc. of 97% alc., containing 1 cc. of 60% $HClO_4$ per 300 cc., is added, and the mixt. is stirred and digested for 15 min. Filter cold through an asbestos Gooch, wash with the alc. soln (30–50 cc. sufficient) dry at 130° C and weigh the pure $KClO_4$ thus obtained. If sulphates of the alk. earth metals are present, dissolve the weighed $KClO_4$ in hot water, dry the Gooch at 130° and weigh again. The sulphates will remain on the filter after this treatment and can thus be corrected for. ED.

31. **The mechanics of solidity.** REGINALD G. DURRANT. *Nature*, **106**, 440–1 (1920); cf. Innes, *C. A.*, **15**, 194.—Hardness is due in part to closeness of at. packing, and diversities in hardness depend also on how far each substance tested is removed from its melting point. *Coeffs. of expansion* themselves depend partly on how far the mean range of temp. from which they are calcd. is removed from the m. p. For strict comparison "corresponding temps." should be taken. If this is done for coeffs. of expansion of gases, then the values become identical; with solids the coeffs. should approach but never reach uniformity. W. H. ROSS. (*C. A.*)

32. **Thermal conductivity of some solid insulators.** J. R. CLARKE. *Phil. Mag.*, **4**, 502–4 (1920).—The relation proposed by Thornton (*C. A.*, **14**, 682) that the thermal cond. of a substance is equal to the product of the coeff. of elasticity and the d. is tested by the data for a number of Jena glasses. No agreement is found. S. C. L. (*C. A.*)

33. **Clay, report on the clays worked by the Longwood Tessellated Tile Co., Ltd., at Longwood.** L. KEITH WARD. S. Australia Dept. of Mines, *Mining Review*, **32**, 38–40 (1920).—The clays worked here consist of residual clays resulting from the weathering or the underlying slate. Most of the clay is iron stained, but by careful selection clay can be obtained which will burn almost white. It is thought that part of the clay is suitable for stoneware, though at present the mfgs. consist mainly of flooring tile with subordinate amts. of roofing tile and common brick. Some of the clay is highly siliceous and could possibly be used for refractory purposes.

D. D. SMYTHE

34. A microscopic study of vein quartz. SIDNEY F. ADAMS. Stanford Univ. *Econ. Geol.*, **15**, 623–64 (1920).—The study is confined to veins of hydrothermal origin and to chalcedony and quartz, the most common varieties of silica in veins. (I) A. describes the varieties found in the different types of veins, gel structures, and structures developed in quartz crystd. in free space. The common chalcedony type is cryptocryst., in spherical, botryoidal, and similar structures. These are usually inherited from a gel state. Fibrous chalcedony is also described. Chalcedony is usually found only in deposits formed near the surface, and is almost invariably subordinate to quartz. Normal quartz is found in all ranges of deposition. Anomalous varieties, feathered and flamboyant, are found only in low-pressure deposits and may be accessory or prominent. Deep-seated veins characteristically consist of interlocking aggregates of normal quartz crysts. in uniform structure. Superficial veins show diversity of structure—crustification in banded, comb, cockade, and spheroidal structure, and colloform structures in microcryst. quartz and chalcedony. Uniformity and lack of it characterize deep seated and shallow veins, respectively. (II) Replacement quartz, replacement structures in fissure veins, and effects of pressure on quartz. Replacement quartz is usually anhedral except when the structure is inherited from the previous mineral, such as easily sol. minerals as calcite. This leads to lamellar or radial structures of the quartz. Pressure results in uneven extinction, various inclusion patterns, shredded quartz due to extreme shearing, and recrystn. of quartz by molecular rearrangement in a crystal to relieve its strained condition. The latter is absent in deposits formed near the surface and its presence may be taken as indicating formation at depth. Many excellent photographs are included. A. B. PECK. (*C. A.*)

35. Kaolin of Indiana. W. N. LOGAN. Ind. State Dept. of Conservation, *Bull.* **6** (1920); *Econ. Geol.*, **15**, 542 (1920).—The beds occur at or near the top of the Mississippian in several counties in the S. W. part of the state. All beds have sandstone above and shale below. Only slight com. development has taken place to date, although large quantities of high-grade white clays are present. The discussion covers the physical and chem. properties of the kaolin, geological conditions of occurrence, origin, uses, and distribution by counties. Earlier explanations of origin are disproved. Lab. expts. and microscopical examn. show that the origin is biochemical. Certain S bacteria are believed to be able to secrete kaolin. The S bacteria obtain S from pyrite in the shale. H_2SO_4 formed attacks the shale and the resulting compd. reacts with quartz of the sandstone, S being replaced by SiO_2, forming kaolin.
A. B. PECK. (*C. A.*)

36. Glass sand. Glass sands of Kentucky. C. H. RICHARDSON. *Ky. Geol. Survey*, [6] **1**, 1–149 (1920).—The first half of the rept. is devoted to a general discussion of glass, its properties, classification, raw materials and methods of mfg. Following this comes a description of the glass sands of Ky., which are divided into three geog. groups. In the last 40 pages are given

anal. of sands from the previously described deposits, anal. of fluxes suitable for use in the mfg. of glass and a bibliography dealing with the more imp. works on glass sands and the glass sand ind.

37. **Barite.** Dept. of Mines, S. Australia, *Mining Review*, **31,** 90 (1920).—An extensive deposit of good barite is found at Pernatty Lagoon near Uvocalla, S. Australia. The occurrence is in crystals and blocks associated with gypsum in clay. A considerable quantity has been obtained and sold but the deposits are not being worked at present.

38. **Clay. The clays and shales of Virginia, west of the Blue Ridge.** H. Ries and R. E. Somers. Va. Geol. Survey, *Bull.* **20,** 1–118 (1920).—This rep. is the third and final no. in a ser. dealing with the clay resources of Virginia. The first few pages are devoted to a short discussion of the geol. occurrences and phys. props. of clays in gen. For discussion in detail, the clays are grouped according to geol. formations. In each of these groups the deposits are divided according to counties and then described individually. These descriptions give both the geol. features and the phys. tests of the clays.

39. **Graphite.** Dept. of Mines, S. Australia, *Mining Review*, **31,** 18, 52–6 (1920).—A bonus of 1 : per ton is offered on marketable graphite produced from any mine in S. Australia and sold prior to June 30, 1922. Development work is being continued by the Uley Graphite Syndicate. It is stated that there are 5000 tons of 11% ore blocked out and 10,000 tons of "probable" ore.

40. **Mica. The geology of the Lomagundi mica deposits.** H. B. Maufe. S. Rhodesia Geological Survey, *Short Rep.* **10,** 1–8 (1920).—This recently opened field, covering an area of over 40 sq. miles, lies along the W. flank of the Angwa river basin in the N. central part of the Lomagundi district. The country rock is principally a mica schist with a few outcrops of various igneous rocks. The merchantable mica occurs in pegmatite dikes varying in width from a few inches to as much as 45 ft. The books of mica occur in the pegmatite along the contact with the mica schist, or surrounding horses of mica schist included in the pegmatite. In places the books are in contact with each other. The mica is entirely muscovite, the books of which vary in length from 4 or 5″ to as many feet but seldom exceed a thickness of 6″. Thus far the mica has been extracted from open cuts having a max. depth of 35 ft. The feldspar of the dike is decomposed so that in most cases the extraction is made without the aid of powder. The mica is sorted and trimmed on the ground by the natives, only the trimmed mica being shipped as yet. As the av. yield is 1.5 lbs. trimmed mica from ea. 100 lbs. mined, a great deal of waste, which as yet is not being utilized, is accumulating.

D. D. Smythe.

See also Book Reviews.

Whiteware and Porcelain

41. Maximum temperature allowable for insulation. ANON. *Elec. World*, **77**, 154 (1921).—Tests for heating should be made at the rated voltage, frequency, and load for which the app. is rated under conditions equiv. to operating conditions. The three methods are: detn. of the temp. by Hg or EtOH thermometers, by resistance thermometers, and by thermocouples or resistance temp. detectors applied to the hottest accessible parts. Tables give the permissible temps. and hottest spot corrections for insulating materials of different classes, also the temp. coeffs. for Cu.

W. H. BOYNTON. (*C. A.*)

42. The mechanical properties of porcelain and exact methods for determining same. E. ROSENTHAL AND F. SINGER. *Chem. Zentr.*, **24**, 675 (1920); *Elektrotechn. Z.*, **41**, 705–6, 9/9.—Porcelain insulators must meet mechanical conditions as well as having the desired elec. props. Authors claim to have developed a hammer, swinging as a pendulum, for applying a definite shock test to porcelain which gives comparative readings.

WM. M. CLARK.

43. Suspension type of transmission line (porcelain) insulators. ALFRED STILL. *Elec. Rev.*, **78**, 135–8 (1921); cf. *C. A.*, **15**, 472.—This instalment covers the design and construction of porcelain suspension insulators; discussion of advantages of thick porcelain in suspension insulators, etc.

C. G. F. (*C. A.*)

44. Chemical pottery. J. W. MELLOR. *Pottery Gaz.*, **46**, 245–7 (1921).—The success of many chem. industries often depends upon the ability of the porcelain to withstand chemicals. The body usually consists of 2 parts clay, 1 part feldspar and 1 part flint. Vitrified ware is best suited to withstand the action of chemicals. Porous ware even when glazed is unsatisfactory since the glaze may crack or peel or contain pinholes. Glazed porcelain, however, enables ppts., etc., to be easily removed. The glaze should have as near the coef. of expans. of the body as possible, thus reducing the tendency of the body to break when subjected to sudden temp. changes. A thin glaze would produce smaller strains than a thick glaze. Salt glazes produce less strains than sprayed glazes. The mechan. strength of ceramic bodies is not nearly as high as that of metal, hence reinforcement with metal bands is often desirable.

45. Translucency and the resistance of porcelain to firing. TH. HERTWIG-MÖHRENBACH. *Sprechsaal*, **54**, 1–2 (1921).—The acid and alkali contents of a number of porcelain bodies were varied. Small boxes (with lids) were then cast and their color, translucency and resistance to deformation observed after firing.

1. $\left.\begin{matrix} 0.65\ K_2O \\ 0.35\ CaO, ZnO \end{matrix}\right\}$ $2.8\ Al_2O_3, 14\ SiO_2$ This body has 12.7% shrink., is highly translucent and retains

	Acid ratio 1 : 1.49	its shape well
2. 0.8 K_2O 0.2 CaO, ZnO	2.8 Al_2O_3, 17 SiO_2 Acid ratio 1 : 1.8	This body looses its shape badly in firing
3. 0.8 K_2O 0.2 CaO, ZnO	2.8 Al_2O_3, 18 SiO_2 Acid ratio 1 : 1.91	This body looses its shape more than No. 2
4. 0.83 K_2O 0.17 CaO, MgO, FeO	3.59 Al_2O_3, 16.36 SiO_2 Acid ratio 1 : 1.38	This body retains its shape well at cone 14
5. 0.65 K_2O 0.35 CaO, MgO, FeO	3 Al_2O_3, 11 SiO_2	This body retains its shape well but is not translucent

Increasing the Al_2O_3 and SiO_2 contents in porcelains decreases the translucency and increases the resistance to deformation. The following glaze is recommended for cone 9 porcelain:

$$\left.\begin{array}{r} 0.2\ K_2O \\ .2\ MgO \\ .5\ CaO \\ .1\ ZnO \end{array}\right\} 0.5\ Al_2O_3,\ 4\ SiO_2$$

With body 1 and this glaze a high class porcelain may be made at cone 9.

H. G. SCHURECHT

Brick and Tile

46. Sand-lime brick—description and specifications. ANON. Bur. of Standards, *Circ.* No. **109**.—Sand-lime brick were first produced in the United States in 1901. By the action of steam under pressure, the lime is caused to combine with some of the sand, forming a hydrated calcium silicate. This material acts as a bonding agent to hold the rest of the sand together. Most sand-lime bricks will compare favorably with "first common" clay bricks. They are characterized by their straight edges, parallel faces, and nearly white color. Sand-lime brick is not a refractory material. A good sand-lime brick for general purposes should have an absorption of not over 20%, an average comp. strength of not less than 2000 lbs. per sq. in., and an average modulus of rupture of not less than 450 lbs. per sq. in. H. F. S.

PATENTS

47. A brick-drier. CHARLES H. KLEIN. U. S. 1,368,940, Feb. 15, 1921. A drier, comprising an alleyway having hollow side walls formed with a plurality of ducts connected with a suitable source of forced drying medium, a car movable into and out of the alleyway with its sides adjacent to but spaced from the side walls, the car having a tier of superimposed pallets spaced upwardly apart and adapted to hold pallets of spaced bricks thereon, the ducts being arranged in the opposite side walls of the alleyway to form separate superimposed strata of drying medium across the spaces between the superimposed pallets so that the drying medium is forced across the

lowermost space, between a pair of pallets immediately above and so on back and forth across the spaces between the pallets from the bottom to the top of the car and finally exhausting outwardly above the car.

48. **Method of and means for supporting tiles, more especially while subject to heat treatment.** PHILIP D'HUC DRESSLER. London, England. U. S. 1,368,219, Feb. 8, 1921. The method of treating tiles, consisting in arranging the tiles with their surfaces vertical to form a plurality of horizontal rows of tiles and supporting the rows of tiles in superposed parallel sets, the edges of the tiles being inclined to the horizontal and the horizontal rows of tiles in one set being arranged in staggered relationship and parallel to those in an adjacent set.

49. **Tile-sorting machine.** BRADLEY L. BENSON. U. S. 1,369,377, Feb. 22, 1921. An apparatus having a series of parallel inclined worms having their lower ends positioned beneath the hopper, a device for raising and lowering the end of the hopper, a rotating brush mounted within the hopper for the purpose of regulating the flow of the tile therefrom, guides mounted beneath the worms, a device causing the tile to be sorted to ride upon the guides, a cam carried on the end of each of the worms, vacuum cups positioned between the ends of the worms, an arm carried on each of the vacuum cups and adapted to engage one of the cams, the vacuum cup being adapted to engage the smooth surface of the tile delivered by the worms, and withdrawing therefrom for the purpose of proper distribution and means for releasing the tile so engaged from the vacuum cup.

50. **Manufacture of hollow tile and the like.** FRANK DOCHNAL. U. S. 1,369,522, Feb. 22, 1921. A method of making hollow tile which is to be finally used as open end tile, which consists in forcing through a die, providing a temporary end wall tie section, or sections, of the tile with a plurality of lines of slotted perforations for weakening the end of the wall tie section, or sections, so they may be easily broken out by the tap of a convenient tool after being burnt and prior to being laid into a wall structure.

C. M. SAEGER, JR.

Glass

51. **Scientific glassware made at Vineland, N. J.** *Glassworker*, **40**, 19 (1921); from Vineland *Daily Republican*.—The plant covers 9 acres, has 7 furnaces and employs 700 workers. A gen. description is given of the methods of making chem. ware, lab. app. and thermos bottles. Most of these products replace those imported from Germany and Austria before the war.

52. **Various methods of silvering of glass.** *Glassworker*, **40**, 19 (9121).—The method of H. Halle (*Handbuch der Praktischen Optik*) is given in full detail. Also the method used by Brashear and an improved method by M. Schair is given.

53. Hints on the melting of watch glasses. *Schnurpfeil's Review for Glass Works,* **4,** 767 (1921).—Three qualities are made, finest, medium and ordinary. Satisfactory batches are given. 1st grade, sand 100, potash 35, lead 35, saltpetre 5, lime 10, manganese $^1/_4$. 2nd grade, sand 100, potash 35, barytes 10, lime 10, saltpetre 3, arsenic $^1/_2$, manganese $^1/_4$. 3rd grade, sand 100, potash 17, soda ash 17, saltpetre 2, lime 14, arsenic $^1/_2$, manganese $^1/_4$. The glass must be absolutely free from bubbles, blown into large balls of correct curvature and uniform thickness. After annealing the watch-glass panes are cut out and finished.

54. Composition of selenium ruby glass. Schnurpfeil's *Review for Glass Works,* **4,** 771 (1921).—Sand 100, soda ash 42, borax 12, lime 8, selenium 1.25, cadmium sulfide 1.75. Used for lantern globes.

55. Composition of glass for lamp chimneys. Schnurpfeil's *Review for Glass Works,* **4,** 771 (1921).—Sand 100, soda ash 33, lime 10, lead 6, barytes 6, borax 1, saltpetre 2, manganese 0.25.

56. A glass etching ink. Schnurpfeil's *Review for Glass Works,* **4,** 771 (1921).—Take 2 parts HF, 2 parts NH_4F and 2 parts precipitated $BaSO_4$ and rub together in a china mortar. Transfer to a lead cup, add fuming HF and stir with gutta-percha rod. R. J. MONTGOMERY.

57. Transmission and refraction data on standard lens and prism material with special reference to infra-red spectroradiometry. W. W. COBLENTZ. Bur. Standards, *Sci. Papers* **401,** 701–14 (1920); *J. Optical Soc. Am.,* **4,** 432–47 (1920).—Optical consts. are given for *glass,* CS_2, quartz, fluorite, rock salt, and sylvite. A classified bibliography is added. W. F. MEGGERS. (*C. A.*)

58. Decolorization of glass by metallic selenium. SABURÔ TSUBOI. Dainihon Yôgyô Kyôkwai Zasshi. *J. Soc. Jap. Ceram.,* **338,** 44–7 (1920).—By addition of 0.003–0.005 Se to 5000 soda glass, the latter is tinged with a beautiful rose color splendid in transparency. Fifty parts of glass are decolorized by 0.02 As_3O_2, 0.003 Se, and 0.001 Co flint, without leaving any dark shades. The color does not change on annealing. K. K. (*C. A.*)

59. Some applications of the photoelectric (selenium) cell to practical photometry. W. E. STORY, JR. *Trans. Ill. Eng. Soc.,* **15,** 827–47 (1920).—The photoelec. cell seems capable of easy adaptation to measuring the c. p. of incandescent lamps in factories. Diagrams of arrangements for this purpose are shown and discussed. The cell used was made according to the procedure of Kunz. D. MACRAE. (*C. A.*)

60. Calculations for glass raw materials and batches. L. SPRINGER. *Die Glashütte,* 50, 787 (1920).—Information regarding selenium compounds; S and S compounds; As_2O_3 and Sb_2O_3; nitre and nitre substitutes; equivalence of potash and soda nitre.

61. Calculations for glass raw materials and batches. L. Springer. *Die Glashütte,* **49**, 771 (1920).—Covers compounds of Co, Ni, Cu, Ag, Au and U, grades found on the market and proportions to use.

62. Calculations for glass raw materials and batches. L. Springer, *Die Glashütte,* **48**, 759 (1920).—Covers SnO_2; federweiss (talcum); coloring, decolorizing and clarifying agents; Fe, Mn, and Cr compounds.

63. Pyrex glass. Anon. *Chem. Zentr.,* **23**, 643 (1920); *Chem. Weekblad,* **17**, 465 (11, 9).—Physical constants are stated as d. 2.25; coeff. of elasticity 6230 kg/mm^2; refractive index 1.4754; linear coeff. of expans. (19–350°) 0.0000032; sp. ht. 0.20; thermal cond. 0.0027; softening temp. 750°.

64. Marking Glass Vessels. *Punde Chem. Zentr.* **24**, 657 (1920). Permanent marking on glass or porcelain is produced by scratching the surface with a sharp aluminum point and in this manner vessels may be calibrated in the laboratory.

65. Sodium silico-fluoride and phosphate opacifying agents. L. Springer. *Glashütte,* **46**, 723–4 (1920).—Calculations of equivalence of different sources of fluorine in glass are shown together with examples of substituting other sources of alumina and fluorine to replace cryolite. Similar exposition is given of the diff. raw materials and equiv. of sources of phosphoric acid.

66. Technical heat consultation office of the German glass industry. Anon. *Glashütte,* **47**, 740–1 (1920).—Incorporated advisory and standardizing bureau founded by the Assoc. of German Glass Ind., Frankfurt. Describes the purposes of this new coöp. bureau for improving fuel conditions in the glass ind. by the utilization of low-grade fuels and endeavoring to derive the utmost attainable thermal effect from all commercial fuel sources.

67. On the annealing temperature of glass. F. Weidert and G. Berndt. *Chem. Zentr.,* **23**, 642 (1920); *Z. f. Tech. Phys.,* **1**, 51–8.—Annealing temp. is defined as that temp. at which the movement of the molecules is so great that the internal stresses in glass immediately vanish, *i. e.,* (the Maxwell time of relaxation is very small). Six glasses from the Sendlinger optical works were examined (two crown, two flint, two Ba glasses) so that the difference of refractive index of the ordinary and the extraordinary rays (which furnish a a measure of the internal stresses) could be measured after cooling through a series of temps. between 200 and 600°C. If the relation of the stresses after and before cooling are plotted as ordinates and the temp. of disappearance as abscissas we obtain for each glass a hyperbolic curve with a sharp bend a definite temp. (the annealing temp.) and which proceeds further horizontally or (owing to incipient devitrification) begins to rise again. The position of the sharp bend is found to be independent of the size of the piece, and, within certain limits, of the method of cooling. The temps. were compared with Schulz's softening temp. and with Zschimmer's cohesion temps. The former, which has only theoret. significance, signifies that temp. to which a glass must at least be chilled so that its internal stresses

are infinitely large. The cohesion temp. signifies that temp. at which two superimposed glass plates weld together. It is a function of the size of the piece, the kind of surface contact, and especially of the time of heating; for a period of 30 min. it approaches the softening temp. as has been shown with a series of Jena glasses. The annealing temps. of the Sendlinger glasses of the same optical properties (and approx. of the same chem. compn.) lies about 70 to 110°C lower than the softening temps. of Jena glasses. The deformation temps. of the Sendlinger glasses were determined, *i. e.*, the temperature at which, on the polished surface, a prism (with a 25 mm. edge) placed on edge and one-half embedded in kiesselguhr made an impression. After 6 hours heating the first impression was noted. This averaged about 30°C lower than the cohesion temp.; for the flint glasses about 40 to 50°C lower and of the four remaining glasses about 70 to 110°C higher, than the annealing temps. The order of increasing deformation temps. for these glasses is the same as the order of increasing annealing temps. These are characteristics of the special types of glasses but are also functions of the temp. intervals and sizes of pieces. For a prism with a 50 mm. edge (about eight times the mass) the temp. is about 40 to 50°C lower while an increase to a 75 mm. edge produced no further change. WM. M. CLARK.

PATENTS

68. **Glass forming machine.** CLYDE R. LOTT. U. S. 1,369,679, Feb. 22, 1921. An apparatus having a blank mold, a sliding bottom movable lengthwise of the mold and forming a closure for the mold during such movement, and a forming device at the opposite end of the mold and coöperating therewith for forming a blank during the inward movement of the bottom, the forming device being brought into its operative position in the mold before the inward movement of the bottom.

69. **Glass.** MAURICE A. SMITH. U. S. 1,365,797, Jan. 18, 1921. A glass having low coefficient of expansion and high resistance to high and low temps., the glass being made from a batch consisting of a preponderance of silica, smaller amounts of B_2O_3, Al_2O_3, $NaNO_3$, and Na_2CO_3, and still smaller amounts of $CaCO_3$ and As_2O_3.

70. **Glass-molding.** FREDERICK W. MILLER. Hockley Heath, England. U. S. 1,368,958, Feb. 15, 1921. A method of molding consisting in fusing powdered or comminuted material in a metal mold thereby causing the fused material to adhere to the mold, and dissolving the mold from the fused material

71. **Method of gripping and cutting sheet glass.** HUDSON S. CAMPBELL. U. S. 1,367,858, Feb. 8, 1921. The method of cutting glass consisting in nicking the glass while in a plastic condition, and subsequently heating the glass along the line of the nick.

72. **Glass-casting table.** WILLIAM J. GOLIGHTLY. U. S. 1,366,786. Jan. 26, 1921. A plate glass casting table, foundation means therefore,

transversed bars between the foundation means and the table, and adjusting screws at the ends of the bars for applying force thereto, tending to lift the table.

73. Glass-furnace. ALEXANDER FRANZ PEETERS. Leerdam, Netherlands. U. S. 1,366,745, Jan. 25, 1921. A glass furnace comprising a single melting compartment, and a pair of separate working compartments diverging from one end of the melting compartment and being in permanent, free communication with the melting compartment both above and below the glass level, the longitudinal axes of the working compartments forming angles of considerably less than 90° with the longitudinal axis of the melting compartment; the two side walls of each working compartment being formed with working openings.

74. Process of preventing the accumulation of moisture in drops on glass sheets. JOSEPH H. T. ROBERTS. Meols, England. U. S. 1,369,708, Feb. 22, 1921. The process consists in covering the glass sheet with a transparent gelatinous substance which will absorb the water and prevent its accumulation in drops, and leaving the covering unprotected.

75. Process for manufacture of white clouded glasses, enamels and glazes. EDUARD RITZ. Sao Paulo, Brazil. U. S. 1,366,101, Jan. 18, 1921. The manufacture of white clouded glass, enamels and glazes, which comprises embodying unpurified clouding material in the glass, glaze or enamel with material containing sufficient fluorin to prevent discoloring.

76. Method for making glass melting pots. JOHN A. BECHTEL. U. S. 1,366,861, Jan. 25, 1921. The method of forming clay pots which consists in compacting the clay in a form having the contour of the exterior of the pot to be formed and comprising a plurality of vertical sections, coring out the center portion of the massive clay to form the interior of the pot, and then removing a section of the form intermediate between the top and bottom sections thereof to permit the pot to shrink during the drying operation with the top and bottom sections in position. C. M. SAEGER, JR.

See also abstract Nos. 21, 32, 36.

Cement, Lime and Plaster

77. Colored wall plaster. W. E. EMLEY AND C. F. FAXON. Bur. of Standards, *Tech. Paper* No. **181.**—The plaster is made of calcined gypsum, wood fibre, and other ingredients. By the use of wood fibre dyed with aniline dyes, a fast-colored gypsum plaster can be made. After this has been applied to the wall and allowed to set, the surface may be scrubbed with soap and water, thereby exposing the colored fibres. Beautiful effects may be produced by the variation of color by the use of fibres of different sizes, by different proportions of fibre and by different surface treatments. The finished wall can be scrubbed with soap and water as frequently as desired. H. F. S.

PATENTS

78. Cement-kiln. John Nelson. U. S. 1,366,586, Jan. 25, 1921. A kiln comprising spaced annular walls having a downdraft chamber therein communicating with the space between the walls adjacent to the bottom of the kiln and a baffle plate spirally connected between the walls forming an updraft flue outletting adjacent the top of the kiln.

79. Portland-cement and calcining kiln. John Nelson. U. S. 1,366,585. Jan. 25, 1921. An apparatus for the manufacture of cement comprising an upright furnace, gas rings in furnace adapted for heating the interior thereof, a stack upon the open top of the furnace adapted for the deposit of pulverized ingredients therein, a screen across the bottom blade for the ingredients carried by the shaft of the motor above the screen whereby the ingredients are evenly fed through the latter for descent by gravity through the heat zone of the kiln whereby the ingredients are calcined into cement.

C. M. Saeger, Jr.

80. Making portland cement. R. W. Lesley. Brit. 152,106, July 4, 1919. The hot waste gases from a rotary cement kiln are used to heat retorts containing low-grade carboniferous materials such as oil shale, lignite, low-grade bituminous or cannel coal, etc. The volatile products from the retorts may be passed along a pipe and burned in the kilns or may be used for other purposes, and the ash or residue is added to the calcareous or other ingredients and submitted to the clinkering process, the C in the residue forming a part at least of the fuel required in the process. The ash or residue from the retorts is carried by a conveyor to a hopper to which the cement-making materials are supplied, and the mixt. is passed therefrom into the kilns. The kilns are heated initially by fuel supplied by a pipe. Cf. 11,618, **1891**.

(*C. A.*)

BOOK REVIEWS

Graphite. Hugh S. Spence. Canad. Dept. of Mines, Mines Branch, Rep. No. 511. Pp. 202 and LVI plates. Ottawa, 1920.—This rep. is a general treatise on the subject of graphite with special reference to the Canadian deposits, mining and milling methods. Chaps. I, II, and III deal with the history, origin, composition and economic importance of graphite. Chapt. IV is devoted to graphite in Canada and gives individual descriptions of the various deposits including numerous maps. Chapt. V covers the field of the concentration and refining of graphite, showing numerous flow sheets and diagrams of machinery from mills in the United States and Canada. Chapt. VI disposes of artificial graphite while Chapt. VII deals with the various uses of graphite. In Chapt. VIII statistics of canadian graphite production are given. Chapt. IX is a discussion of foreign graphite deposits. The last chapter (X) is devoted to a discussion of the methods used in the analysis of graphite and is followed by a bibliography and index. At the end are a number of plates illustrating raw and manufactured graphite, graphite mines, and mills.

D. D. Smythe

ACTIVITIES OF THE SOCIETY

Minutes of Meeting Held by Members of American Ceramic Society, for the Purpose of Forming a Heavy Clay Products Division of the Society

Meeting held March 8 at 10 A.M., in Room 1011, Hotel Deshler, Columbus Ohio. Meeting called to order by Mr. F. H. Riddle, acting Chairman—Mr. C. F. Tefft appointed temporary Secretary by Mr. Riddle, until permanent officers could be selected. Fifty members of the Society were present at the meeting.

Organization.—Voted that the Members of the American Ceramic Society assembled in this meeting, organize a Division of the Society under the name of Heavy Clay Products Division—the definition of this term and scope of work to be outlined by a Committee of Five, to be appointed by the Chair.

Voted that the above Committee of Five have power to select and appoint a permanent Chairman and Secretary, the appointment to be made and officers installed at afternoon session, to be held at 2 P.M. in the same location as present meeting. Chair appointed on this Committee the following men: Mr. M. W. Blair, Chairman, Mr. R. K. Hursh, Mr. M. P. Post, Mr. A. V. Bleininger, Mr. Fred Brand.

Reading of Papers.—Reading of paper by Mr. M. W. Blair, "Technical Investigation or Practical Application." Discussion on this paper by Mr. Riddle, Mr. Stevens, Mr. Blair, Sr.

Reading of paper by Mr. R. F. Geller, "The Water Smoking of Clays." Discussion on this paper by Mr. M. W. Blair and Mr. R. K. Hursh.

Discussion of Scope of Work for Heavy Clay Products Division

Mr. Bleininger gave a very interesting talk outlining the program to be followed in research work for the Heavy Clay Products Manufacture. It is planned to devote energies at present to the burning problem. Mr. Blair, Sr., made a very strong appeal to the members present on the advisability of getting a much larger appropriation from the Government for Ceramic Research Work. It appears that the farmers in this country are able to obtain appropriation close to $30,000,000 per year for experimental work to help improve their crops, while the Ceramic field is able to obtain an appropriation of only $3,000,000 per year. Mr. Bleininger, formerly of the Bureau of Standards and Mr. Moore of the Bureau of Mines stated that they would be only too glad to assist in any way possible to get larger appropriations for their work.

Reading of Correspondence from Members not Present.—Reading by Secretary of letters from two members expressing good will toward organization

of Division and regretting their inability to help by their presence. Letters were from Mr. J. R. Thomas, of Standard Brick Company, Crawfordville, Ind., and Mr. E. W. Dailey, of North Iowa Brick and Tile Company.

Adjournment.—Adjourned until 2 P.M.

Minutes of the Afternoon Meeting of the Heavy Clay Products Division of the American Ceramic Society

Meeting held in same room as morning session.

This meeting was called to order at 2 P.M. by Mr. M. W. Blair, Chairman of the Committee of Five, who were to report on the appointment of permanent officers for the Division. Mr. Blair reported the appointment of Mr. R. C. Purdy as permanent Chairman and Mr. C. F. Tefft as secretary. These officers were then installed.

Report of Committee follows: "It is the sense of this Committee that the activities of the Heavy Clay Products Division shall embrace the following interests unless otherwise provided for in the Society rulings: Face Brick, Paving Brick, Common Brick, Hollow Building Tile, Promenade and Quarry Tile, Sewer Pipe, Drain Tile, and any other lines that may properly be included in this Division.

"It is expected that the Division shall act as a clearing house and publicity medium for the information to be derived from the technical investigations proposed to be financed by the Associations actively controlling the above lines. It is urged that insofar as possible the investigations to be undertaken, shall be interpreted and applied in such a way as to be immediately available upon the respective plants represented.

It is also urged that membership be solicited particularly among the men in active charge of manufacturing operations and that they be encouraged in every way to prepare and present papers and discussions for the programs of this Division, dealing with their every day tasks and problems."

VOTED: To adopt this report.

Mr. Purdy in his acceptance of the appointment as Chairman outlined a probable plan of procedure for the next year and stated most clearly that if this Division were to be a success, all of the members must give their support and answer any questionnaires which may be sent them, as complete records from actual practice will be a big help in the work that is planned.

VOTED: That the Chairman appoint a Membership Committee to be made up of at least one member from each of the various industries represented by the Heavy Cay Products Division,—the Chairman of this Committee to be a member of the American Ceramic Society's Membership Committee. Chair announced that this Committee would be appointed later.

Mr. Blair, Sr., again brought up the matter of more financial support from our Government to help in the ceramic industries which are being planned. A discussion of this subject was carried on by Mr. Greenough who felt that we should get more definite information as to just what is planned and the amount of money necessary to carry out the plans before asking for larger appropriations.

VOTED: That the Chair appoint a Committee of Three with power to consider rules and draft a set of by-laws for this Division. The Chair asked for time to consider the appointment of this Committee.

Mr. Stevens called the attention of everyone present to the need of our getting the papers and reports of investigations into the most simple language so that they could be understood by the men at the plants.

Mr. Purdy suggested the best way to get the information contained in these reports to the foreman was to have heart to heart talks with them and study the papers over carefully at these meetings.

Adjourned.

C. FORREST TEFFT, *Secretary*

Actions Taken by the Board of Trustees

March 22. It was voted that the next Annual Meeting of the Society be held at the Hotel Statler, St. Louis, February 27–March 2, 1922.

It was voted that the Board of Trustees authorize the Committee on Publications to appoint a Board of Associate Editors of the JOURNAL.

It was voted to discontinue the membership held in the National Fire Protection Association.

New Members Received During March, 1921

Resident Associate

Austin, G. L., Joliet, Ill., Superintendent, American Refractories Co.

Bitting, A. W., 3344 Michigan Ave., Chicago, Ill., Director of Research, Glass Container Association of America.

Blackburn, C. A., Cleveland, Ohio, General Superintendent "Ivanhoe Plant" Cleveland Metal Products Co.

Burton, R. C., Zanesville, Ohio, President, Burton-Townsend Co.

Clark, Ernest, Terra Cotta, Ill., Superintendent, American Terra Cotta & Ceramic Co.

Cushman, H. D., 1101 Swetland Bldg., Cleveland, Ohio, President, Ferro Enameling Co.

Dana, Leslie, St. Louis, Missouri, President, Charter Oak Stove & Range Co.

Davis, S. E., 929 Division St., South Parkersburg, W. Va., General Porcelain Co.

Earl, Oliver N., Box 97, East Liverpool, Ohio, Harshaw, Fuller & Goodwin Co.

Edson, S. P., Bryantville, Mass., Superintendent and Enameler, Wheeler Reflector Co.

Elledge, H. G., 3384 Webster Ave., Pittsburgh, Pa., Technical Assistant to General Sales Manager, Diamond Alkali Co.

Ewing, R. F., 1602 Clark Ave., Wellsville, Ohio, McLain Fire Brick Co.

Forsyth, J. H., Cleveland, Ohio, Associate Chemist, Glass Technology Dept., National Lamp Works of G. E. Co.

Frazier, C. E., Washington, Pa., President, Simplex Engineering Co.

Frey, Wm. J., 304 W. Adams St., Sandusky, Ohio, Superintendent, Universal Clay Products Co.

Gernon, Ursula F., Brookings, S. D., Craft Instructor, South Dakota State College.

Greenough, Maurice B., 830 Engineers Bldg., Cleveland, Ohio, Secretary, National Paving Brick Manufacturers Association.

Krekel, Albert, 1917 W. Fayette St., Baltimore, Md., Engineer, Porcelain Enamel & Mfg. Co.

Langworthy, H. S., Jewettville, N. Y., Vice-President and Superintendent, Jewettville Clay Products Co.

Little, H. B., Baltimore, Md., President, Baltimore Enamel & Novelty Co.

McGee, Earle N., Syracuse, N. Y., Research Laboratory, Semet-Solvay Co.

Marshall, S. M., 1107 Broadway, New York City, Consulting Engineer, Perin & Marshall.

Metz, G. F., 120 Broadway, New York City, Sales Engineer, Hardinge Co.

Miller, Emerson R., Zanesville, Ohio, Salesman, Mosaic Tile Co.

Minehart, A. G., Jr., Toledo, Ohio, Manager, The Rock Products Co.

Mitchell, Leon W., Rock Island, Ill., Superintendent, Rock Island Stove Co.

Nye, C. P., Uniontown, Pa., Manager, Richmond Radiator Co.

Raiff, David A., Coshocton, Ohio, Enameler, Beach Enameling Co.

Riblet, Bertha, 2047 East 115th St., Cleveland, Ohio.

Riley, R. J., Indianapolis, Ind., Indianapolis Terra Cotta Co.

Rogers, Thomas L., Chicago, Ill., Special Representative, National Silica Co.

Shaw, Lucian, West Lafayette, Ohio, Secretary, The West Lafayette Manufacturing Co.

Theobald, Erwin F., Magnolia, Ohio, Ceramic Engineer, National Fire Proofing Co.

Vance, Edward D., Springfield, Ohio, Ceramic Engineer, Safety Emery Wheel Co.

Vodick, William J., Libertyville, Ill., Chicago Hardware Foundry Co.

Weaver, James P., Box 658, Belle Vernon, Pa., Chemist, American Window Glass Co.

Webster, Henry, 628 Lexington Ave., Newport, Ky., Kiln Expert, Henry Webster & Sons.

Wenning, W. F., Pittsburgh, Pa., Research Dept., Vitro Manufacturing Co.

Williams, C. W., 720 Electric Bldg., Cleveland, Ohio, Harshaw, Fuller & Goodwin Co.

Williams, George A., 173 Johnson Ave., Tottenville, S. I., N. Y., Chemist Atlantic Terra Cotta Co., Perth Amboy, N. J.

Worsham, Edgar A., Baltimore, Md., Assistant Treasurer, Porcelain Enamel & Manufacturing Co.

Foreign Associate

Clare, H. L., Hespeler, Ontario, Canada, Sales Manager, Stamped & Enameled Ware.

Cronshaw, H. B., Ph.D., Brierley Hill, South Staffordshire, England, Principal Technical Institute.

Erdmann, K., Radenthein, Kaernten, Austria, General Director, Austro-American Magnesite Co.

Parkinson, Caleb, Ashdale, Holmfield, Halifax, Yorkshire, England, Manager, Parkinson & Spencer, Ambler Thorn Fireclay Works.

Saito, Hachiro, Omuta, Japan, Chief Engineer, Miike Chemical & Dye Works.

Shaluvalia, Dogar Singh, Stoke-on-Trent, England, Hollin Minton Patent Tile Works.

Stein, Alan, Bonnybridge, Scotland, Managing Director, John G. Stein & Co., Ltd.

Tatsumi, Eiichi, Omuta, Japan, Superintendent, Miike Chemical & Dye Works.

Corporation

Acme Brick Co., 412 Adams Bldg., Danville, Ill.

McLain Fire Brick Co., 508 Fulton Bldg., Pittsburgh, Pa.

Matawan Tile Co., Matawan, N. J.

Mitchell Clay Mfg. Co., 5627 Manchester Ave., St. Louis, Mo.

Old Bridge Enameled Brick & Tile Co., Old Bridge, N. J.

Pennsylvania Pulverizing Co., Lewistown, Pa.

Salem China Co., Salem, Ohio.

The Stark Rolling Mill Co., Canton, Ohio.

Universal Clay Products Co., Sandusky, Ohio.

The Wahl Co., 1800 Roscoe St., Chicago, Ill.

NECROLOGY

Jacob Hasslacher, well known in ceramic circles, died at his home, 322 West 100th Street in the City of New York, on the morning of March 15, 1921, in the 69th year of his age,

Among his friends he was recognized as farseeing and broad in his views and purposes, forceful but tactful, willing at all times to subordinate his own wishes to the good of the cause he supported, liberal to give his friendship, effort and means, sympathetic, an ardent lover and admirer of nature. After many years of active administration in chemical industry he was on account of ill health and to the great regret of his associates compelled to retire from active participation about a year ago. Despite his retirement he maintained an active interest in all his former friends and their activities until a few days before his death.

AMERICAN CERAMIC SOCIETY

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CORPORATION MEMBERS, 1920–1921

Abrasive Company.
Alexander Hamilton Inst.,
American Dressler Tunnel Kilns, Inc.
American Emery Wheel Works.
American Encaustic Tiling Co.
American Terra Cotta & Ceramic Co.

Bausch & Lomb Optical Co.
Beaver Falls Art Tile Co.

Bird and Company
Brick and Clay Record.
Buckeye Clay Pot Co.
W. G. Bush and Co.

Canton Stamping & Enameling Co.
Carborundum Co.
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Homer Laughlin China Co.
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Saxon China Co.
Sebring Pottery Co.
Smith-Phillips China Co.
Standard Pottery Co.
Standard Sanitary Manufacturing Co.
Star Porcelain Co.
Steubenville Pottery Co.
Streator Clay Mfg. Co.
Square D. Co., Peru, Ind.

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R. Thomas & Sons Co.
Trenton Flint & Spar Co.

United States Glass Co.
United States Smelting Furnace Co.

Veritas Firing System.
Vitro Manufacturing Co.
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F. H. Riddle, *Chairman*
Jeffrey-Dewitt Co.
Detroit, Mich.

JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

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Vol. 4 | June, 1921 | No. 6

EDITORIAL

THE PERMANENT SECRETARYSHIP

I have looked ahead for many years to the time when the American Ceramic Society could afford to have the full time and full energy of a Secretary of proper qualifications. All who were on the Board of Trustees during the first twenty years will remember that this topic was up before the Board almost every year, not with a recommendation for immediate action, but as a goal towards which we should set our faces and toward the fulfillment of which our annual plans and developments should constantly trend. I can not, at this time, without stultifying myself, do otherwise than add my endorsement to the proposition of full-time Secretary of the proper caliber, which is before the Society for discussion.

I do not wish to take any active part in the discussion of the exact mode of accomplishing this long-considered plan. Those arrangements are for those who are now controlling the work of the Society. I understand there are two plans being discussed: one by which this official should take over the present office of the Secretary, expanding the present functions of the Secretary to include the broader duties of correlating the work of the divisions, securing the coöperation of manufacturers, and in raising funds for research and experiment, *vs.* the other, by which the present Secretary's office would remain undisturbed as a sort of

accounting department, through which funds are collected, membership rosters are maintained, and routine correspondence is handled, and the appointment of an Organizing Secretary to undertake the promotion and scientific development work.

If I have any preference, I lean to the view that there should be but one Secretary's office, and that under him should be concentrated all work which is now being performed and that which we are hoping will be performed by the new full-time officer. My reason for this preference is that I believe that any man big enough to do the promotion work will also be big enough to administer the routine work on the side (especially as it is now pretty well systematized), without making a burden of it. It would conduce towards economy by making only one office force necessary. It would place at the immediate disposal of the Promoting Secretary the basic data as to existing conditions in the Society with which he would have to be constantly familiar. A well-trained bookkeeper or accountant, and a stenographic force of proper size could take care of all routine work of the Society, and enable the Secretary to concentrate his thoughts upon the real creative work.

My experience in a rather wide field of enterprises has brought home to me pretty sharply the fundamental tendency of human beings to build a wall around their job. Our government departments are a fine illustration. It is to be expected, if we run two separate offices, one for the Recording Secretary and one for an Organizing Secretary, that these two jobs would tend to become unnecessarily isolated from each other, and the degree of coöperation between them would probably not be as good as we would wish. This assumption is not intended as a criticism of any existing personnel. It is merely a general comment on a characteristic trait of human nature, and no matter who we secured for the two jobs, it would probably work out much the same in time.

I think we may very well look to the experiences of the older Engineering and Technical Societies in the country as a guide to our own policy. In most of them, if not all, the organization has been built by the skillful and devoted services of some one

officer. Rossiter W. Raymond, for many years the guiding spirit of the American Institution of Mining Engineers, and Edgar Marburg, the Secretary-Treasurer of the American Society for Testing Materials, are good illustrations of what a paid full-time secretary should be. These men found ample time to administer the business affairs of their organizations as a side line, while devoting their best thought and the bulk of their time to the broader problems of promotion and organization.

Of course, in this proposed venture as in all other human affairs, the success of the enterprise will depend upon the man selected. It would be useless to put in a small man into such a job, for a small man will produce small results. Only the services of a first-class man, one who is already earning a big salary and holding down a big job, would be suitable for this place. If the Society will finance the employment of such a person, they will take the surest possible step towards upbuilding both the Society and the whole Ceramic industry. Please notice that I say "*if the Society will finance this venture.*" I do not say *if they can*, for there is no question but what they *can* do it, if they start out to do it. It may call for new methods, and it may make necessary some encroachments upon the invested funds of the Society, but I feel certain that if the Society really wants to put this thing over, they can readily find a way to do it. Being no longer in touch with the Society's finances or income, I do not pretend to advise as to details. I am only arguing on general principles, but I feel very certain that there is nothing impossible about the execution of the plan, and believe that the full development of the American Ceramic Society can not come until the Society does decide to take the plunge and make this big forward step. I believe that the whole status of the American Clay Industries will be at once improved and uplifted by it. Only a big and powerful organization can do for the industries what they need to have done. The American Ceramic Society is the one organization which can do it, and I believe that now is the fateful hour for it to act.

EDWARD ORTON, JR.

THE RELATION OF THE ARTIST TO THE MANUFACTURER[1]

By Conrad Dressler

ABSTRACT

The achievements of the past owed their beauty to the artist. The excellent technique of the present is due to the efforts of the manufacturer and scientist. The latter quality has now almost superseded the former; yet the esthetic needs are eternal and can not be denied. The efforts of solitary artists are unavailing in a modern world of vast undertakings. It is for the modern factory to reintroduce the artistic spirit.

In the beginning there were no manufacturers, only artists. The vestiges of pottery found on the sites of ancient cities show that variety of shape, that charm and interest which we are accustomed to ascribe to the artistic temperament.

Our museums exhibit examples of pottery from all countries and of all periods. Many clays and raw materials were used by a variety of tribes and races. The results were very dissimilar, but each period and country show something which can be called style which differs from other productions, which is self-contained, finished and satisfying. Each such style has a beginning, a growth and a full period of expansion after which it declines in beauty as if exhausted of its vitality.

Nothing that has been done in modern times equals the artistic quality of the Etruscan vases, the Tanagra figures, the Susa frieze of archers, the Persian and Rhodian ware, the Faienza pottery, the Spanish lustre ware, the Blue Nankin china of the 16th Century, or the old slipware of medieval England. All these qualities are due to the artist.

If we have lost these qualities what have we got in replacement?

The modern manufacturing system has given us wonderful things, but it has not given us beauty.

What is beauty?

[1] Received April 7, 1921.

I can not define, and I do not think any one can define what beauty is, but I can tell you what it is not. It is not perfect squareness, absolute flatness, faultless uniformity, pure whiteness, specklessness, or any kind of precision, nor is it dependent on solidity, resistance to blows, frost, and changes of temperature. All these are manufacturers qualities which I am very far from belittling, which, in fact, I think very highly of, which have been achieved by mighty human effort and ingenuity, and which constitute a great advance in the progress of the world's work.

These qualities, however, even when used with the best taste, are from an esthetic standpoint only negative qualities—they are not inspiring and do not stimulate the mind and the imagination. In fact, they leave us cold. It is true, the results of the use of the manufacturers ware need not be vulgar. In the hands of a clever artist they will not offend the eye, but neither will they arouse any enthusiasm, or give any kind of esthetic pleasure.

Thus, if I may say so, the position today is that the arts of pottery (and this applies, I believe, to many other industrial arts) have been pursued exclusively from the point of view of utility. The progress made has been technical. The quality called artistic has gradually become less until it has disappeared. What has taken its place has been soundness and neatness, and often good taste. These purely negative qualities leave many people comfortable and complacent, but they bring no stirring message to the heart or to the mind.

Some people will say, "is it desirable that we should have stirring messages from inanimate things?"

My own feeling is that there are signs that the reintroduction of the artistic creative quality into modern pottery is becoming not merely advisable, but necessary. The people yearn for it and are willing to pay for it. If this is so, the modern world is so constituted that only the manufacturer is now in a position to restore this spirit.

The small outside potter, the individual artist, can no longer hold their own in the great struggle for existence when, in any measure, capital is required to bring a work to perfection. They

may start on some successful experimental work, but when it comes to providing the modern world with what is needed the scale so vastly outstrips their equipment that they have either to develop into a large establishment themselves or to give up the job.

There are so many examples of the hopelessness of these attempts that I will say no more. I have seen William De Morgan's great efforts finally fail—I have had a similar experience myself, and I have had many friends in England and France who have found it impossible to stand up for long against the march of modern factory production. And yet, are we therefore condemned to give up the hope that pottery shall some day be as beautiful and creative as it has been in the past? Shall we never again see messages of emotion and beauty recorded in plastic clay, and are we definitely condemned to either pure utilitarianism or to a cold and soulless imitation of the styles of the past?

I firmly believe that the spirit of our times is pressing towards a solution of this difficult problem. Architects are calling upon the pottery manufacturers for something which shall be typical of the plastic arts, not merely a reproduction of a stone or wooden example out of some museum, or taken from some old building. They want beauty, originality, esthetic emotion.

The manufacturer sees that it is to his advantage to meet these requirements. He calls on artists to help him. In many cases he is prepared to spend large sums to obtain artistic results.

The public again, trained by the sight of so many beautiful objects in the museums of all the large towns, is becoming more and more alive to the quality of beauty.

Thus the elements are being gathered together and it will soon be possible to bring about a change in the methods of work which will once more make the artistic note the dominant one in the production.

I believe that one of the greatest troubles which now exist in factories is due to the lack of interest in the workers. There is a monotony in their task which makes it impossible for them to look for any other reward than money. The training and utilization of their esthetic faculty will do more than anything

else to give zest to their occupation to develop a proper "esprit de corps" and a pride in their workshop community.

That this esthetic faculty exists in a greater or lesser degree in most people is an ascertained fact. That it is an asset worth utilizing is another fact of commercial value. How all this is to be done is a problem which I am not going to offer a solution of, but that it is one which must be solved for the sake of the future of our civilization is an undoubted truism.

To sum up:

The achievements of the past owed their beauty to the artist.

The excellent technique of the present is due to the efforts of the manufacturer and scientist.

The latter quality has now almost entirely superseded the former.

Yet the esthetic needs are eternal and can not be denied.

The efforts of solitary artists are unavailing in a modern world of vast undertakings.

It is for the modern factory to reintroduce the artistic spirit. In so doing it will accomplish two ends. It will bring happiness and contentment as well as enthusiasm and emulation to its workers.

It will give a hungering public new forms of beauty by using in a new way those old plastic materials which have already been so fruitful of wonderful results in the past.

THE SOLUBILITY AND FUSIBILITY OF SOME FELDSPAR FRITS[1]

By H. H. Sortwell

ABSTRACT

Twenty frits were made covering the field 10–50% fused borax, 20–90% feldspar, and 0–30% calcium oxide. (1). The *solubilities* of the entire field were found to be less than 1.5% showing that the variations in composition in this field had less effect on the resulting solubility than the degree of smelting, and that all of the frits were sufficiently insoluble for use in glazes. The inclusion of CaO in the frit had a beneficial effect in decreasing the solubility. (2). The *fusibilities* were found to vary from 660° to 1050°C. Substitution of CaO for feldspar up to 10%, maintaining the borax constant, increased the deformation point, but further substitution in this direction had little effect. Substitution of either CaO or feldspar for borax appeared to raise the deformation temperature about the same in either case. A large part of the field was sufficiently fusible for easy working in the frit kiln.

Introduction

In ceramic literature there is a lack of definite information on the solubility of frits for whiteware glazes.

That frits in commercial use are sometimes poorly chosen in regard to solubility was shown by Blumenthal,[2] who determined the solubility of several frits now in use, the compositions of which were unknown.

There are some qualitative data as to what compositions are insoluble and what soluble, but no studies have been made showing the ranges of the materials ordinarily fritted, in which frits of sufficiently low solubility for judicious use in glazes lie.

As a beginning toward the accumulation of such data, a field of frits composed of feldspar, whiting, and borax was made, and the solubilities and, incidently, the fusibilities determined.

[1] Published by permission of the Director, Bureau of Standards. Received March 10, 1921.

[2] Blumenthal, George, *J. Am. Ceram. Soc.*, 3, 152–154 (1920).

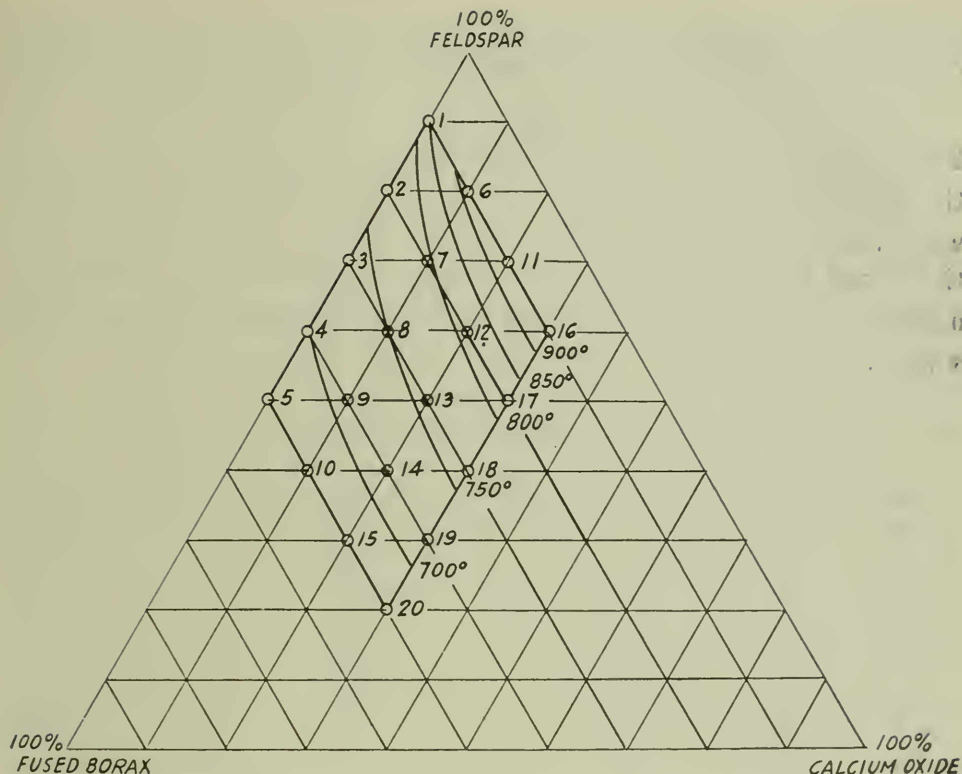

FIG. 1.—Deformation temperatures of used frits.

Experimental

Table 1 shows the melted and raw compositions of the 20 frits made covering the range, 10–50 per cent fused borax, 20–90 per cent feldspar, and 0–30 per cent calcium oxide.

The Maine feldspar used analyzed:

SiO_2	72.85
Fe_2O_3	0.48
Al_2O_3	15.45
CaO	0.31
K_2O	7.89
Na_2O	2.31
Loss on ignition	0.25
	99.54

The frits were weighed out separately, throughly mixed, fused in crucibles and poured into water. As nearly as could be judged, each frit was given just the heat treatment necessary to properly fuse it, in order to avoid as much as possible variations in the re-

sults which would be introduced by the difference in the degree of smelting, as shown by Poste and Rice[1] in their work on enamels.

The solubilities were determined by the method employed by Blumenthal,[2] which consisted of taking five grams of frit sized through 20-mesh and retained on 40-mesh, with 350 cc of distilled water, agitating 24 hours in a rotary shaker, making 17 revolutions per minute, allowing to settle one-half hour, and determining the suspended material and the amount of material dissolved.

Table 1

Composition of Frits

No.	Percentage melted Feldspar	CaO	$Na_2B_4O_7$	Raw batch Feldspar	Whiting	Borax
1	90	..	10	900	...	189.2
2	80	..	20	800	...	378.4
3	70	..	30	700	...	567.6
4	60	..	40	600	...	756.8
5	50	..	50	500	...	946.0
6	80	10	10	800	178.6	189.2
7	70	10	20	700	178.6	378.4
8	60	10	30	600	178.6	567.6
9	50	10	40	500	178.6	756.8
10	40	10	50	400	178.6	946.0
11	70	20	10	700	357.2	189.2
12	60	20	20	600	357.2	378.4
13	50	20	30	500	357.2	567.6
14	40	20	40	400	357.2	756.8
15	30	20	50	300	357.2	946.0
16	60	30	10	600	535.8	189.2
17	50	30	20	500	535.8	378.4
89	40	30	30	400	535.8	567.6
1I	30	30	40	300	535.8	756.8
20	20	30	50	200	535.8	946.0

To determine the fusibilities, test cones of standard size were made from the frits passed through 100 mesh, using gum tragacanth for a binder. The fusions were made in a small chromel electric resistance furnace. The temperature measurements were made with a platinum-rhodium thermocouple and a potentiometer indicator. The cold junction of the thermo-

[1] Poste and Rice, *J. Am. Ceram. Soc.*, **1**, 221–233 (1918).

[2] *Loc. cit.*

couple was maintained at zero by means of an iced thermos bottle. The temperature was raised at the rate of 10° C per minute.

Results

Solubility Determinations.—The results of the solubility determinations are shown in table 2. The entire field was sufficiently insoluble for use as frits in glazes. The degree of smelting has greater effect on the solubility than the variations in composition covered in this work. The frits having the greatest solubilities, a little over one per cent, are those consisting of borax and feldspar alone. From this it would appear that a little whiting has a beneficient effect in reducing the solubility.

Fusibility Determinations.—Difficulty was experienced in determining the fusibilities by cones due to the tendency of the borax to segregate at the bottom of the cone, leaving a skeleton of the harder materials. This would occur in successive fusions of the same frit in varying degree. This difficulty has been experienced before in this laboratory in studying the fusibility of enamels for metals. Difference in the degree of melting would also affect the results.

Therefore, the results obtained are only approximate, being the average of several cones of each frit which appeared to fuse with the least segregation. They serve satisfactorily as a basis for comparison and are fairly consistent.

Examination of figure 1, which is a graphical representation of the field showing the isotherms as approximately indicated, shows that replacement of either feldspar or calcium oxide by fused borax lowers the deformation temperature about the same amount in each case.

Substitution of calcium oxide for feldspar maintaining the borax constant increases the deformation temperature up to 10 per cent calcium oxide. Further substitition in this direction has but slight effect in increasing the temperature of deformation.

The deformation temperatures of three representative frits now in use being made in frit-kilns fired by both coal and gas were determined as a criterion of the proper fusibility for frit-kiln frits. These were found to be 717°, 690° and 773° C, respectively.

Judging by these figures and the behavior of the frits in the crucibles, it was estimated that approximately 800° C was about the maximum deformation temperature of the melted frit for easy working of a frit in the ordinary hearth frit kiln.

Consulting figure 1, it is seen that the number of mixtures in this field suitable for frits is large.

TABLE 2

RESULTS

Solubilities and Fusibilities

No.	Deformation temperature °C	Suspended material per Cent	Soluble matter per Cent
1	865	0.21	0.25
2	773	.17	.67
3	720	.09	1.05
4	700	.04	1.08
5	660	.19	1.51
6	943	.16	.24
7	805	.18	.47
8	765	.07	.23
9	715	.07	.40
10	685	.14	.76
11	875	.15	.62
12	810	.10	.21
13	765	.07	.63
14	715	.05	.68
15	692	.09	.98
16	1056	.10	.23
17	810	.16	.38
18	765	.14	.58
19	715	.08	.42
20	702	.02	.63

NOTE ON COBALT STAIN IN WHITE WARE BODIES

By Arthur S. Watts[1]

ABSTRACT

Faulty methods of adding cobalt.—Cobalt oxide or directly added cobalt sulphate frequently causes a blue-gray cast when the body is hard fired.

Correct preparations of stain from cobalt sulphate.—To 750 ounces of pure water add 15 ounces pure cobalt sulphate ($CoSO_4 + 7H_2O$) and stir until dissolved. Then add 7.5 ounces of carbonate of soda (Na_2CO_3) and stir thoroughly.

Adding stain to body.—Ball clay must be thoroughly blunged with body before adding stain. If used in a casting slip, add the stain as a part of the casting solution.

Proportions stain to body.—For a body containing 10 per cent ball clay add 75 ounces stain solution to each 1500 pounds body, *i. e.*, $^1/_2$ ounce stain for each 10 pounds body. For bodies with higher ball clay content increase the stain addition in the same ratio up to 15% ball clay.

Stain in glazes.—Add 10 ounces stain to each 100 pounds dry glaze batch when same is thoroughly wet in mill. For glaze high in lead, the amount of of stain required is increased.

On numerous occasions I have observed that the cobalt stain, used to neutralize the normal yellow tint of white ware bodies, is still made from cobalt oxide and in every case of this kind the amount of stain required to overcome the yellow cast is so great that, if the body is overfired ever so lightly, the result is a distinct blue gray cast. On numerous other occasions I have found white-ware manufacturers using cobalt sulphate dissolved in water and without any salt added to precipitate the cobalt in an insoluble form. The amount of cobalt added in this form is also frequently in excess of that necessary to neutralize the yellow cast of the body. I find that there is a common impression that to convert the soluble cobalt into a form which is insoluble or only slightly soluble in water will cause specks to appear in the ware. For these reasons I desire to offer a procedure for adding cobalt to a white-ware body which I have employed with uniform success for several years.

[1] Received March 10, 1921.

1. **Preparation of the Cobalt Sulphate Solution.**—To 750 ounces of pure water add 15 ounces of pure cobalt sulphate ($CoSO_4 + 7H_2O$) and stir until all the cobalt is dissolved. Then add 7.5 ounces of carbonate of soda (Na_2CO_3) and stir thoroughly for several minutes. The product will be a milky pink liquid which will settle with difficulty. Provide ten one-gallon fruit jars with covers and in each place 75 ounces of the stain, stirring the batch thoroughly to prevent settling during the process of dividing.

2. **Adding the Cobalt Stain.**—As soon as the ball clay has thoroughly blunged up in the batch of body, you may add the stain and no sooner. If desired, the stain need not be added until about five minutes before the body is drawn off into the cistern. This cobalt stain can be poured into the blunger without fear of causing dark specks.

3. **Proportioning of Stain to Body.**—The above cobalt solution is designed to be used in the proportion of 75 ounces of stain to 1500 pounds of a body containing ten per cent ball clay, or one-half ounce of stain for each 10 pounds of body. If the ball clay content is increased, I find the amount of stain should be increased in the same ratio but if the ball clay content exceeds fifteen per cent of the body, it is impossible to produce a pure white product by increasing the cobalt stain.

If the body is to be used for casting and a mixture of carbonate of soda and silicate of soda is added, I find it advisable to introduce the cobalt sulphate directly into the casting solution before it is added to the body. The silicate of soda will cause the precipitated cobalt solution to change from a pink to a dark purple, but this does not apparently change its properties in the body.

4. **Stain in Glazes.**—I have found this stain very satisfactory for neutralizing the yellow tint of white-ware glazes. To every hundred pounds of glaze being ground add 10 ounces of the stain. This should be added after the glaze has been put into the mill and the water added. If the glaze is very high in lead, the required amount of stain will be greater, but for the average white-ware fritted glaze the above proportions will be found very satisfactory.

Columbus, Ohio

THE VALUE OF AGEING THE TERRA COTTA BODY[1]

By R. L. Clare and R. N. Long

ABSTRACT

It is shown that the terra cotta body when aged for a period of twelve days improves in plasticity, workability and strength. If the body is aged and subsequently repugged, still greater improvement is noted. This process is recommended as developing to the fullest extent the latent qualities of the body. The theory of this action seems to be a softening of the clay grains which with the retempering process results in a finer subdivision of the particles and a more intimate combination of the clay and grog.

Purpose of the Investigation

In an effort to produce the best possible finished product, the relative value of ageing or storing the terra cotta body mixture, as against using the freshly tempered mixture, is a question which should be carefully studied. Many of the ceramic industries, such as the white ware, porcelain insulator, chemical stoneware and glass pot plants, have adopted this method in conjunction with their clay preparation as vitally necessary to the production of good material. Various other of the industries, such as roofing tile, refractory, sanitary ware and terra cotta companies, have found this method to be of great advantage to them and, while not universally adopted, it is found in some of the plants.

It is noted that those industries which have adopted this method to the greatest extent are those making the most difficult wares, which, of course, require the best possible body mixtures that can be produced within economic limits. The terra cotta manufacturers are probably required to make a greater variety of difficult shapes and sizes than any other ceramic industry, yet it is one of the industries that has not universally adopted this method of body preparation.

This investigation was conceived, therefore, to develop some accurate data on the effect on the body mixture caused by the ageing of the body and to show by these facts whether there

[1] Received April 7, 1921.

were any decided advantages to be gained by this extra operation and the extra expense involved. Also, in some of the plants the ageing process is accompanied by a subsequent tempering to get better uniformity, which is unquestionably good practice. We, therefore, extended our investigation to cover the aged and retempered body as well as the aged body without retempering.

The first point to be determined was the proper length of the ageing period. Preliminary tests were made of the working qualities of clay aged one, two and three weeks, the latter being about the practical limit for terra cotta plants. From these observations, it was found that after one week there was a marked change for the better in the clay; after two weeks, there was a slight further improvement, but after three weeks no further change was noted. We, therefore, selected twelve days as the length of the ageing period for these experiments.

We also found that if proper care is taken of the clay and it is not too soft when stored, retempering is not necessary unless still greater strength and plasticity is desired.

Experimental

All of the test pieces were made up from one batch of body mixture. A part of this was made into samples directly after it had been pugged, and marked "A," representing the fresh mixture such as is used in many plants. The remainder of the batch was stored away in the ageing cellar for twelve days when another set of test pieces was made and marked "B," representing what we found to be a well aged clay. The balance of the clay was then repugged, allowed to stand over night, and pressed into test pieces marked "C." This treatment we thought should develop the highest plasticity and greatest strength.

All of the pressing was done by one of our best men and the test bars were so designed as to reduce to a minimum any variation due to the human element. Observations were made during the pressing of each set of pieces so as to determine the plasticity, workability and finishing qualities of the various lots of clay. All the pieces were dried carefully and those to be used for burning were fired to cone 6 in a commercial terra cotta kiln.

Table 1 gives the results from the test pieces and the observations made.

TABLE 1

Test	Body A Fresh mixture	Body B Aged 12 days	Body C Aged 12 days and repugged
Water of plasticity (dry basis)	29.4%	26.1%	23.7%
Linear drying shrinkage (wet basis)	5.76%	5.41%	4.82%
Drying warpage	0.187″	0.094″	0.120″
Drying cracks	None	None	None
Transverse strength (dry)	121.3 lbs. per sq. in	128.5 lbs. per sq. in.	160.1 lbs. per sq. in.
Plasticity and workability	Worked fairly well. Somewhat short. Some cracking while in the mold. Finished piece looked ragged.	Worked better, more plastic, no cracking in molds. Piece finished up much better.	Worked very well. Very plastic. No cracking in molds. Piece finished up better than preceding sample.
Burning shrinkage	2.56%	2.46″	2.53%
Burning warpage	0.143″	0.187″	0.184″
Absorption	17.68%	17.57%	16.58%

The water of plasticity shows a progressive drop, even though some little water was added to body "C" when repugged. This can only be explained as due to evaporation. The linear dry shrinkage checks the results obtained above.

For the purpose of studying the effect of ageing on the tendency of the body to warp in drying, ten test pieces 2″ × 4″ × 16″ were pressed solid in plaster molds and as soon as they were stiff enough to support their own weight without deforming, they were set up on end and allowed to dry at room temperature, protected from air currents. The amount of warpage was then measured by placing a straight-edge across the concave face and the deflection from the straight-edge measured in hundredths of an inch. The figures in the table are the average of ten tests. This shows body "B" to be decidedly straighter after drying

than "A," and body "C" shows an improvement over "A" in this respect, but not as much as "B." The results of this test were very consistent.

The transverse strengths of the dry bodies were determined by breaking ten bars, approximately 1″ × 1″ × 8″ on a 6″ span and the modulus of rupture computed according to the formula:

$$M = \frac{3PL}{2bd^2}$$

(where P is the load in pounds and L the span in inches). We had hoped that this test would be a fairly accurate measure of the increased plasticity and strength developed by the ageing and repugging operations. The difference between 121.3 lbs. per sq. in. and 128.5 lbs. per sq. in., however, does not adequately show the marked difference between bodies "A" and "B." The increase in strength of body "C" to 160.1 lbs. per sq. in. is remarkable, as it shows the undeveloped possibilities in the average body. The character of the fractures in each of these bodies is interesting. All of the breaks of the body "A" bars are very ragged and seldom under the knife edge. Those for body "B" were nearly all directly under the knife edge and not quite so ragged as "A." Those for body "C" were all directly under the knife edge and showed a comparatively smooth break, indicating a very fine grained clay.

The plasticity and workability show a progressive improvement in the bodies "A," "B" and "C." This was determined from observations made from full-sized terra cotta pieces pressed in the shop from each of the bodies. These results, while not measurable, were very marked and check with the preceding data.

The burning shrinkage results indicate that the ageing had no particular influence on the vitrification behavior.

The warpage during firing was measured by the deflection of a bar 2″ × 2″ × 17″ suspended on clay triangles 12″ apart and set in the kiln with a $1^1/_2$ lb. weight in the center of each bar. The weight was used to magnify any slight difference which might occur. These results show a very slight increase in warpage for bodies "B" and "C."

The absorption test was made after a twenty-four hour soaking period and two hours boiling. Bodies "A" and "B" are practically the same with "C," 1 per cent lower. This we attribute to the finer subdivision and closer combination of the particles after ageing and repugging.

Theory of the Ageing Process

From the data above, this ageing action seems to be chiefly a slaking or softening process, together with a more uniform distribution of the moisture between the clay and grog grains. We know that ordinary pugging of the mixture does not entirely break up all of the clay particles nor does it thoroughly saturate the larger grog grains. The ageing period, however, allows time for the moisture to soak into these clay particles and to saturate the grog grains so that the resultant mixture is a more uniform and workable mass, but with little or no change in the subdivision of the clay. The retempering process then breaks up these softened particles and produces a finer subdivision of the clay and a more intimate combination of the clay with the grog. A stronger and more plastic mixture is the result. This theory is borne out by the data which indicate a very slight increase in dry strength for the aged body and a very considerable increase when this body is aged and then repugged.

There may be some benefit from bacterial growth or "rotting" of the clay as claimed by some investigators,[1] but this was not evident in this work after a twelve day period. If ageing were mainly dependent upon the bacterial action, then the increase in dry strength should be as apparent in the aged body as in the aged and retempered clay.

Conclusions

Ageing of a terra cotta body for twelve days without subsequent retempering materially increases the plasticity and workability of the clay, slightly increases the dry strength and reduces the tendency to warp in drying. This produces a mixture easier to press and finish, straighter and somewhat stronger in the dry state than the un-aged clay. All of these qualities tend to reduce losses and to insure a better finished product.

Retempering of the body mixture, afer ageing, produces a slight increase in plasticity and workability over the aged body, increases the tendency to warp in drying slightly, and produces a very marked increase in dry strength.

This last quality tends to materially reduce the losses from chipped and broken pieces and allows of greater freedom in handling the dry material. A body such as this would be much safer to use in the manufacture of large pieces than clay that has been aged without retempering.

This process is to be recommended to the terra cotta industry as developing to the fullest extent the latent qualities of the clay mixture used.

References

[1] Ogle, *Trans. Amer. Ceram. Soc.*, **3**, 171 (1901); Stover, *Ibid.*, **4**, 183 (1902) and **5**, 358 (1903); Spurrier, *J. Am. Ceram. Soc.*, **4**, 113 (1921).

NOTE ON SAGGER CLAY PREPARATION[1]

By F. K. Pence

ABSTRACT

Better mixture of ingredients.—Saggers can be improved in quality by installing a mixing machine immediately following the dry pan. The *soaking pit* may then be eliminated and the clay and water fed directly to the pug mill. This process permits of *large tonnage* and is of course also applicable to other bodies.

In contributions on the subject of sagger making, much emphasis has rightfully been placed upon the composition of the sagger body, the nature and quality of the clays used, the percentage of grog, the size of grinding, etc.

Another factor having a vital influence upon the resultant quality of the sagger is the method by which the various ingredients of the sagger body are brought to the state of plastic mixture ready to be moulded into the sagger.

We are all familiar with the old dry pan, soaking pit, pug mill process by which the body was brought to a condition of apparent homogeneity. Some have used the wetpan as a pugging device in order to develop plasticity and secure more intimate mixture of ingredients. This is a disadvantage from the standpoint of capacity as the wetpan is a retarding element.

Extensive observations led the writer to believe that improvement in quality could be obtained by insisting on greater homogeneity in the body mixture. In the old soaking pit method, a semblance of mixing was obtained by the manner of grinding the clays and filling the pit, and the pugging was supposed to complete the process of securing uniformity. However, by altering the procedure as described briefly below, the following, a distinct improvement in quality, was noted.

An experiment was made in which the proper amounts of ground clay and grog were intimately mixed in an ordinary cement mixer before any water was added. The mixture was

[1] Received March 10, 1921.

then wet down and pugged through in the regular way. The results obtained were so satisfactory that the process of dry mixing as a means of securing intimate uniformity became a matter of important attention. Further investigations confirmed the results of this preliminary experiment to the end that the writer strongly recommends the installation of a device of sufficient capacity immediately following the drypan, whereby intimate dry mixing of all ingredients may be secured. The remainder of the process may now be as before, but the status of the mixture makes possible a greater efficiency at this point.

The soaking pit may now be eliminated and the clay and water fed into a double pug mill and auger machine to produce a bar of plastic clay as in a stiff-mud brick installation. This clay can be cut into proper lengths, and made at once into saggers with good results. However, if this clay is stored for a period of thirty-six to forty-eight hours or longer, covering with damp cloths to prevent evaporation, a further marked development of working properties will be secured.

The process as outlined in the foregoing admits of large tonnage capacity and applies, of course, to the preparation of plastic clay mixtures other than sagger bodies.

Zanesville, Ohio

APPLICATION OF ELECTRIC HEAT TO VITREOUS ENAMELING[1]

Lawrence E. Barringer

ABSTRACT

A two-compartment open-chamber furnace with separating door operated from the outside is described. The source of heat is an electric current passed through a nichrome resistor ribbon wound over refractory supports arranged along the sides of the furnace. The front or preheating compartment is operated at 300°C and the back or finishing compartment at 900°C, with automatic control. The advantages, compared with oil heating, are: rejections reduced from 25 per cent to zero; 50 per cent increase in output for same floor space; 47.4 per cent lower fuel cost; improved quality and uniformity; lower maintenance cost and greater ease of operation.

For some years the writer has believed that electric heat would prove ideal for the heating of furnaces used in enameling work where the conditions are quite suitable for the direct application of this method of heating.

Electric heat has often been discussed with reference to various ceramic operations, but in some branches of the art there are difficulties which would prove insurmountable at this time and which would necessitate radical and expensive changes in kiln or furnace design and plant arrangement. The situation is rather complex, for instance, when one considers the possibility of applying heat to pottery kilns. The space to be heated is large and the transmission of heat from the electric sources would be difficult. The heat conductivity of pottery ware and saggers is low and therefore the even distribution of heat either by convection or by conduction would be, with the same types of furnace, much more difficult with heat from electric energy than from coal, oil or gas.

Then, too, the temperatures involved in pottery operations are comparatively high and increase the difficulties of uniform firing, particularly in the manufacture of porcelain, as electrical porcelain, spark plugs, etc.

[1] Received March 7, 1921.

In enameling work, however, the conditions are such as to make possible not only the successful application of electric heat, without serious disturbance of furnace equipment or plant arrangement, but to offer also distinct advantages in the system of electric heating. The muffle furnaces employed are of comparatively small volume, the temperatures are relatively low and well within the range of metallic ribbon resistor construction and the conductivity of the ware is high as compared to green clay wares and saggers.

An electrically heated enameling furnace has been described by Mehling and Carpenter,[1] but the writer wishes to bring to the attention of the Society a further step in the application of electric heat to vitreous enameling work involving the treatment of enameled resistors in a furnace of two compartments with two heats and other special features.

The enameled resistors in question consist of special refractory tubes, or cylinders, made from a fire clay or refractory oxide mixture and fired in porcelain kilns. Upon these spools wire is wound to give the required resistance for units of each class and then enamel is applied over this wire and fused to the usual smooth, glassy, impervious coating. This coating completely embeds the resistance conductor and protects it from moisture, oxidation or mechanical disarragement, thus providing a most durable construction. The enamel employed in this work is of the same type used in ordinary metal enameling and the furnace temperatures lie within the same range.

When this work was started some years ago by the General Electric Co., the work of enameling the resistors was done in the metal enameling shop. After a year or two, however, it was found that the results were not altogether satisfactory, due to a rather high loss because of cracked tubes or spools. This cracking of the resistor spools was caused by sudden heating and cooling and the handling of this class of ware was more difficult than with enameled metal, which will withstand rapid temperature change without physical injury. To cool the enameled resistors slowly was found easy of accomplishment by transferring the

[1] *J. Am. Ceram. Soc.*, **4**, 271 (1921).

racks from the enameling furnaces to closed sheet iron cooling chambers constructed very much like the warming closet in a butler's pantry but the gradual heating required could not be secured with the oil-fired enameling furnaces in use.

An electrically heated furnace was then designed and built by the General Electric Co.'s electric furnace engineers and has been a pronounced success from the outset, not only in reducing rejections and giving a very much improved quality of ware,

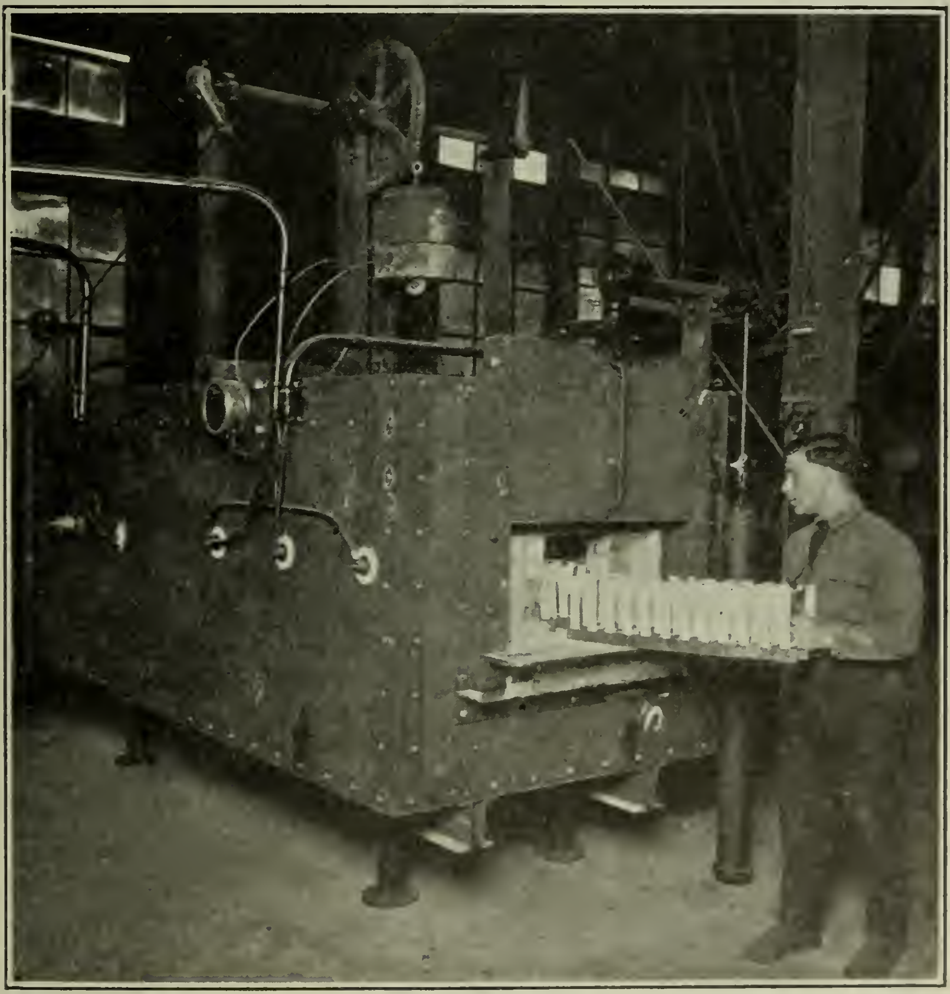

FIG. 1.—Electric vitreous enameling furnace, charging preheating chamber. Preheating chamber 4′ long, 18″ wide, 24″ high inside, 9 kw-300°C operation. High temperature chamber 4′ long, 18″ wide inside, 24″ high, 24 kw-900°C operation.

but also in the matter of cost, having proven a substantial economy over the oil-fired furnace.

The furnace is shown in figure 1. It is substantially built of boiler iron and fire brick. The heating chamber is an open tunnel without muffle and is divided into two compartments by a fire clay door or damper which moves vertically so that it can be raised or lowered as a charge of ware passes from one compartment to the other. Each compartment is 4 ft. long by 18 in. wide by 24 in. high. The ware is placed on sheet steel racks which pass through the furnace on guide rails. Counter weights facilitate moving the dividing door and long handles are arranged so that it can be operated from either end of the furnace.

This feature of graduated or compartment heating is one which would be difficult of accomplishment with other sources of heat, but is very easily secured by electric heat through simply providing the proper resistance and supplying the proper current.

The front compartment of the furnace is used for pre-heating the enamel-coated devices at a temperature of 300° C. This is necessary, as above noted, because if the resistors are subjected to too great an initial heat, many crack. The connected load on this chamber is 9 kw. and the time required to complete the pre-heating of a charge of ware is about 6 minutes.

When the pre-heating is accomplished, the charge is moved into the second compartment, through the centre door, by raising the partition from the outside. In this second compartment the ware is subjected to a temperature of 900° C. for about six minutes, emerging in a finished state. The load on the 900° C side is 24 kw.

The heating units in the furnace are of nichrome ribbon wound over refractory supports composed of highly heat-resistant material and arranged along the sides of the furnace in such a way as to give very even heat distribution.

The control is automatic, the Leeds & Northrup automatic temperature regulator being employed. A view of the control board is shown in figure 2.

There is no difficulty in maintaining a uniform temperature

for indefinite periods ensuring uniformity of quality and regularity of output.

Besides the work of firing enameled resistors with fire-clay bases, for which the furnace was originally constructed, the

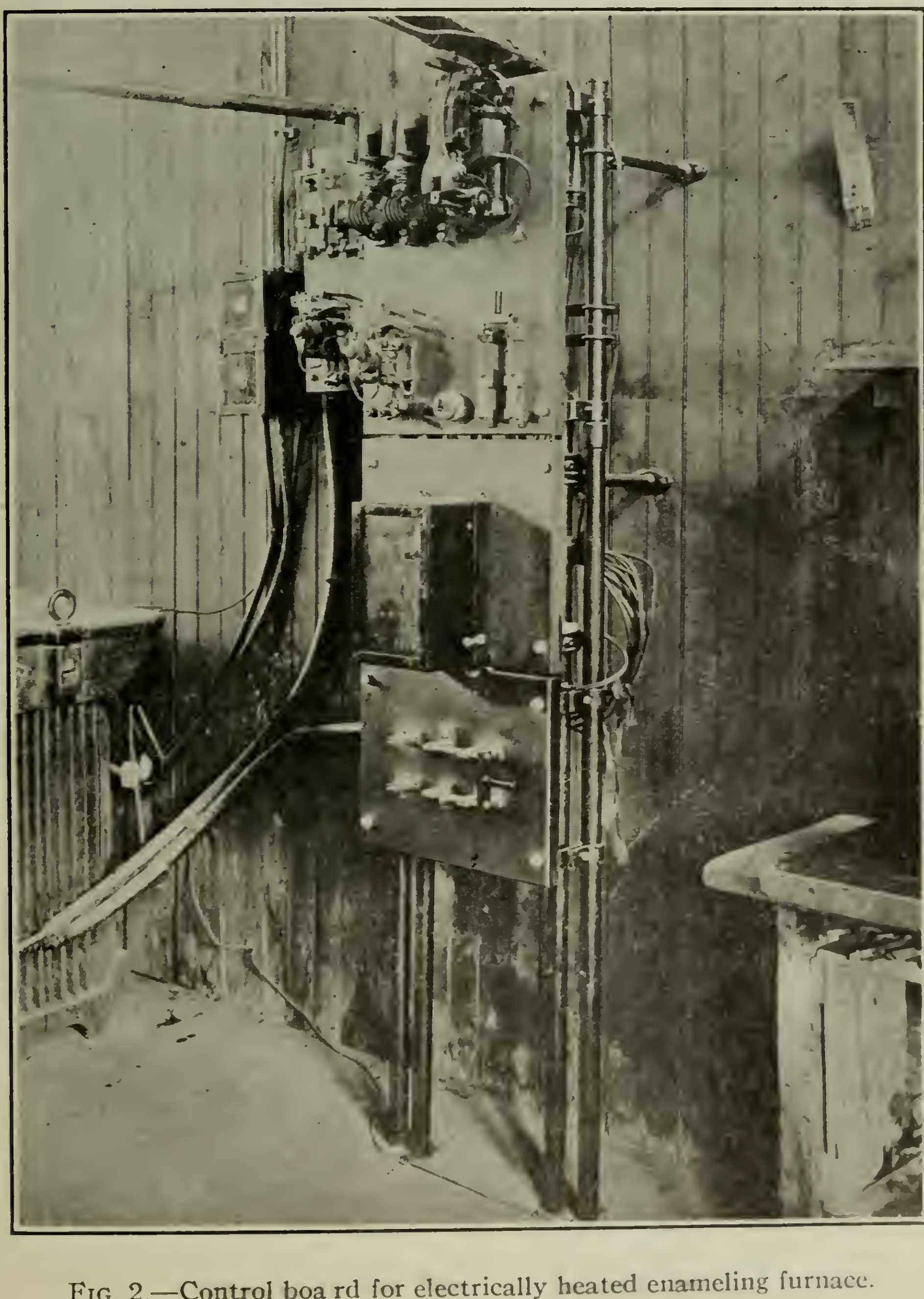

FIG. 2.—Control boa rd for electrically heated enameling furnace.

firing of enameled metal parts has also been carried out with much success and an unexpected advantage was secured in the enameling of steel push buttons. A red enamel is applied to the ends of these buttons to serve as an indicating color to operators. In firing them in the standard oil furnace the edges were

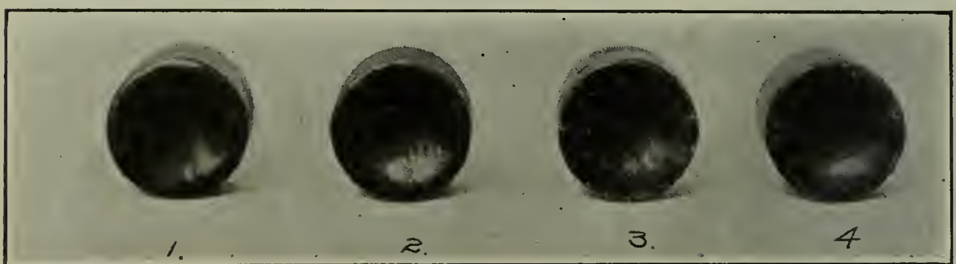

FIG. 3.—Enameled push buttons, numbers 1 and 2 fired in electric furnace; numbers 3 and 4 fired in oil furnace.

never altogether satisfactorily covered and the buttons were frequently found with the enamel shrunken back from the edges or chipped. In the electrically heated furnace the result has been smooth, well-covered edges free from defects as shown in figure 3. The reason for this is left to the reader's determination, but must certainly lie within the conditions of a graduated and even temperature and freedom of the electric furnaces from fuel gases, or other deleterious by-products present in coal or oil-fired furnaces.

As to cost of operation, the following tabulations show "cost runs" made with the furnace handling the products above mentioned.

TABLE 1

Hours run, 4.
KWH consumed, 97.3.
Fired 11 loads of push buttons, 48 pieces per load or 528 pieces.
Weight of push buttons, 52 lbs.
Weight of 11 racks, 121 lbs.
KWH per lb. of load, 0.562.
KWH per lb. of push buttons, 1.87.
Cost per lb. of push buttons, $0.02338.
Cost per push button, $0.0023.

Table 2

Hours run, 1.33.
KWH consumed, 43.8.
Fired 9 loads of 35, $6^1/_2$" resistance tubes or 315 tubes.
Weight of 35 tubes, 9 lbs.
Weight of rack, 13.5 lbs.
Weight of 315 tubes, 81 lbs.
Weight of 9 racks, 121.5 lbs.
Total weight, 202.5 lbs.
KWH per lb. of tubes, 0.541.
KWH per lb. of tubes and racks, 0.266.
Cost per lb. of tubes and racks, $0.00028.
Cost per lb. of tube, $0.00676.
Cost per tube, $0.0017.

With the oil furnace that this electric furnace has replaced, the oil consumption was an average of 6 gallons per hour. At 13 cts., the price of fuel oil at the time, the cost per hour was $0.78. The cost of operating the electric furnace, taking the figures of table 2, which have been found maximum rather than average, the cost of the electric furnace for current is $0.41 per hour. There is thus a direct saving of $0.37 per hour or 47.4%.

In this installation, therefore, the following advantages have been secured by substituting electric heating for oil heating.

1. Reduction of rejections from 25% to practically zero.
2. Increase of 50% in output without increase of floor space.
3. Fuel saving of 47.4%.
4. Improved quality.
5. Higher degree of uniformity.
6. Fewer furnace repairs and lower cost for maintenance.
7. Greater ease of operation.
8. Furnace heated up more quickly by elimination of muffle.

The writer believes that most, if not all, of these advantages are available to any factory producing enameled ware or specialties and that the electrically heated furnace will be the furnace of the future for this branch of the ceramic industry.

Research Laboratory
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THE ABSORPTION OF SODIUM HYDROXIDE BY KAOLINS[1]

By R. F. Geller and D. R. Caldwell

ABSTRACT

Amounts of NaOH absorbed by kaolins.—The amounts of sodium hydroxide completely absorbed by North Carolina, Georgia and Florida kaolins, without showing the presence of free alkali sufficient to color phenolphthalein are, respectively: 0.125%; between 0.100% and 0.125%; and between 0.225% and 0.250% of the dry weight of the clay.

Effect of time and temperature on absorption.—The absorption appears to be largely independent of time but increases with temperature.

Nature of the absorption process.—The experimental data can be expressed by the Freundlich adsorption isotherm thus indicating that the adsorption process belongs to the category of adsorption phenomena.

Introduction

The present work was undertaken for the purpose of determining the percentage of sodium hydroxide removed from solution by kaolin and to establish, if possible, whether the removal of the alkali represents a case of absorption or whether it is due to chemical combination under the assumption that we are dealing with a quasi-kaolinic acid. Such information is desirable in dealing with the deflocculation of kaolin in the purification process.

In this paper the term "absorption" will be used to designate the removal from solution of a dissolved substance by a solid, regardless of the mechanism by which this occurs. "Adsorption" may be considered as a special form of absorption, characterized by the accumulation of the dissolved substance upon the surface of the solid.

If an attempt were made to titrate the excess alkali in the presence of the clay, it would be found that no sharp end-point could

[1] Published by permission of the Director, Bureau of Standards. Received March 23, 1921.

be secured either with indicators or with a hydrogen electrode. This behavior is probably due to the fact that as the alkali in the solution is neutralized, the equilibrium with the clay is disturbed, not alone by the change in the alkali concentration, but also by the presence of the neutral salt produced. The above difficulties could probably be avoided by a direct measurement of the hydroxyl (or hydrogen) ion concentration of solutions of increasing alkali content containing the clay in suspension. Such measurements could no doubt be made by means of a hydrogen electrode. As opportunity offers it is hoped to investigate this method of study.

Experimental

The materials used were typical samples of washed Georgia, North Carolina and Florida kaolins. In the method employed by us, definite amounts of alkali were added to the clay and the solid matter was removed by centrifuging after standing for some time. The alkali was then determined in the liquid. The material to be tested was dried at 110° C and for each determination samples of fifty grams were used with an addition of 400 cc. of distilled water. After addition of the desired amounts of sodium hydroxide, the containers with the suspension were shaken mechanically for one hour and allowed to stand for 23 additional hours. The supernatant liquid and the suspended matter were then centrifuged in a Sharpless machine rotating at from forty to fifty thousand revolutions per minute. Although a liquid free from visible solid particles was obtained, it still probably contained some colloidal matter so finely dispersed that it would pass through filter paper. This solution was made acid by means of 0.01 normal sulphuric acid, and the excess of acid was then titrated in the boiling hot solution with 0.01 normal sodium hydroxide, using phenolphthalein as the indicator. The calculated amount of alkali necessary to neutralize all of the acid added, less the amount of sodium hydroxide required to neutralize the excess acid, is equivalent to the alkali left free in the solution after interaction with the clay. The sodium hydroxide absorbed is then found by subtracting this free alkali from the amount added to the clay. The following results were obtained:

TABLE 1

Amounts of NaOH Absorbed by 50 Grams of Kaolin from 400 Cc. of Solution

	NaOH added grams/liter	NaOH absorbed expressed as % of clay	NaOH absorbed expressed as % of NaOH added
A. N. Carolina kaolin	0.125	0.100	100.00
	.156	.125	100.00
	.187	.148	98.67
	.250	.192	96.00
	.312	.208	83.20
	.375	.229	76.33
	.437	.252	72.00
	.500	.254	63.50
	.625	.286	57.20
B. Georgia kaolin	0.125	0.100	100.00
	.156	.122	97.60
	.187	.146	97.33
	.250	.173	86.50
	.312	.205	82.00
	.375	.211	70.33
	.437	.231	66.00
	.500	.239	59.75
	.625	.265	53.00
C. Florida kaolin	0.125	0.100	100.00
	.250	.200	100.00
	.281	.225	100.00
	.312	.240	96.00
	.343	.257	93.50
	.375	.265	88.33
	.437	.281	80.29
	.500	.301	75.25
	.625	.356	71.20

The results for all the clays were found to check very satisfactorily. It will be noted that in all cases when small amounts of alkali are added, all of the reagent is absorbed by the clay, or at least insufficient is left in solution to be detected by phenolphthalein. With the North Carolina clay the centrifuged liquid was very pale yellow, indicating the presence of organic or inorganic matter dispersed as a colloidal solution.

It appears from the results for the Georgia kaolin that the absorption, in spite of the greater fineness of this clay, is less pronounced than with the other kaolins, indicating that the material

already contains absorbed matter. The centrifuged liquid differed in color from light to dark yellow according to the amount of free alkali remaining in the solution, indicative of an appreciable amount of organic and other substances of a colloid character. With the Florida clay the centrifuged liquid was a clear yellow in color. These results show that the absorption power of the Florida kaolin is decidedly greater than for either of the preceding ones. This would indicate greater fineness since, if the absorption is a case of adsorption, it is proportional to the specific surface. In using sodium hydroxide as the absorbed substance, there is, however, a possibility of chemical reaction with the clay owing to the acid nature of the latter, which complicates the situation.

Rate of Absorption.—In order to determine the rate of absorption, a suspension of 50 grams of the Georgia clay was allowed to stand with 400 cc. of solution containing 0.625 gram per liter of sodium hydroxide, for different periods of time up to 96 hours, and the following results were obtained:

Time in hours....................	0.25	1.00	24.00	72.00	96.00
NaOH absorbed per cent of clay....	0.276	0.283	0.265	0.287	0.289

The maximum absorption therefore takes place quite rapidly and even after ninety-six hours the amount taken up is only 2.4 per cent greater than the quantity absorbed after one hour.

Effect of Temperature.—It is evident that in systems of this kind the absorption is also a function of the temperature. By allowing only one hour for the reaction, but raising the temperature to 90° C, the amount of alkali absorbed by Georgia kaolin from a solution containing 0.625 gram per liter of sodium hydroxide was 0.342% as compared with 0.265% under conditions of normal temperature. This marked difference appears to be due to chemical reaction of the alkali, which is to be expected. With Florida kaolin, under the same conditions, 0.41% of sodium hydroxide was absorbed at 90° C as compared with 0.356% at room temperature. The smaller change introduced by increased temperature, with the Florida clay, may be connected with the deviation from the normal curve (Fig. 1).

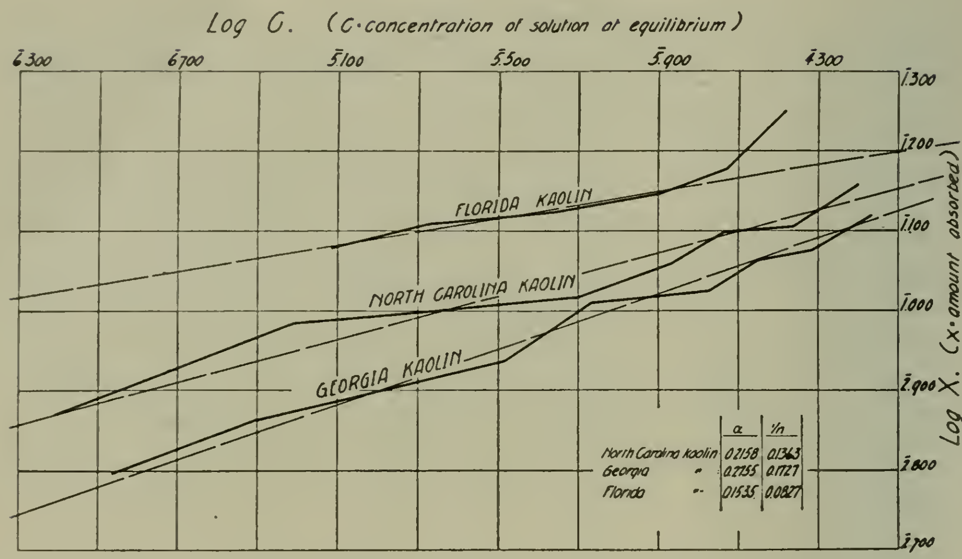


FIG. 1

The Absorption Isotherm.—The Freundlich equation for the absorption isotherm, $x/m = \alpha C^1/n$, in which x equals grams of NaOH absorbed by m grams of the absorbent, C the volume concentration of NaOH at equilibrium, and α and n are constants, was applied to the experimental data. The results obtained by plotting the logs of x and c are shown graphically in figure 1. It is evident that if the above equation holds the resulting curves must be straight lines. By comparing the plots obtained for each clay with the mean straight line, it will be found that while there are variations, the agreement in general is good. The Florida kaolin shows the straight line relationship particularly closely up to the higher concentrations of alkali, but then it departs sharply from the straight line. The constants, α and $1/n$, of the Freundlich equation for the three clays studied are indicated on the graphs.

It is believed that this field of study, employing other electrolytes, offers many possibilities for the more exact differentiation of the different types of clays, especially where the cruder methods of mechanical analysis fail. Thus the absorption of malachite green proposed by Ashley is a measure of the plasticity of clays, which is undoubtedly useful in estimating the relative specific surface of the materials, though to what extent such absorption

is influenced by electrolytes and non-electrolytes already absorbed remains to be seen.

The further study of absorption phenomena for different clays is suggested, especially with solutions involving no direct chemical action.

The writers wish to acknowledge the assistance of Mr. A. V. Bleininger in outlining this work.

BUREAU OF STANDARDS, WASHINGTON, D. C.

TESTING COKE OVEN REFRACTORIES[1]

By F. A. Harvey and E. N. McGee

ABSTRACT

General Requirements are stated for mat, bench walls, checker work, regenerator korbels, main flues, division walls, oven chambers and jamb blocks. The following *Tests* are described:—inspection, reheating tests on three qualities, bending test.

Requirements and specifications are discussed. The latter part of the paper deals with *Apparent density* and *Permanent expansion*. It is shown that the relation between them is a linear one and a chart is given. The average of thirty-nine determinations gives an apparent density, for Western brick, 0.016 higher than for Pennsylvania brick, due to the fact that the Western ganister is slower to transform than the Eastern.

Introduction

The proper testing of refractory materials requires a clear understanding of the conditions both ordinary and extraordinary, which the materials will be called upon to meet. The word "failure" applied to refractories has a very wide range of meaning. Under given conditions the average life may be only a few weeks, while under others it may be several years. We will, therefore, define "failure" loosely as a life considerably shorter than the average. "Failures" may be placed in three classes: (1) Due purely to a lack of understanding of ordinary conditions to be met; (2) Failure to take account of abnormal conditions—*i. e.*, too low a safety factor; (3) Faults of operation. due either to accident, ignorance, or carelessness. As illustrations of *the first*, we might cite the use of low heat duty clay brick, where high heat duty are required, or the use of silica brick where they are subjected to repeated rapid temperature fluctuations at a fairly low temperature; or the use of some home-made or patented cement or fire-mortar at a temperature higher than its fluxing point. To illustrate *the second*, the necessity of carrying the full steam load of a plant on two boilers on a four boiler

[1] Received March 10, 1921.

plant for short periods, or the high temperature which may be reached in the regenerators of a block of coke ovens, due to a break down in the reversing mechanism; or the possible increased temperature reached in the oven-chamber due to a breakdown in the pusher, coal or coke handling or larry cars, which prevents pushing ovens on schedule. For *the third*, we might cite running a coke-oven plant at a higher pushing rate than the material of construction will allow, or failure to correct hot spots due to leakage or excess gas. Many other illustrations might easily be cited. The testing engineer is concerned with all three classes of failures; the first he should eliminate entirely; the second is a balance between cost of materials and cost of possible repairs; and the third is a matter of education of the operators as to what the materials in his care will stand.

General Requirements

We shall attempt to state conditions for a modern regenerator plant, starting from the concrete mat. It is customary to use several courses of clay brick just above the mat. The temperature reached varies according to construction, but it is normally quite low, probably not over 600° C to 700° C. There are no temperature fluctuations to meet. The load is very high as the full weight of the battery is carried. Uniformity of size is essential.

Next come *the foundation walls*, or bench walls. It is customary to make these walls of silica brick. The temperature requirements are fairly low except in cases of severe leakage, due to wrong design. There is very little change in temperature. The brick must be thoroughly burned. Permanent expansion must be very low to prevent creeping of the substructure, spoken of below. The load is very high. Uniformity of brick and very thin mortar joints, to prevent settling, are essential. Silica brick are necessary, due to the fact that they will carry the heavy load without the gradual shrinkage which clay brick would show.

The *Checker work* of the regenerators usually consists of clay brick for the lower courses, silica brick for the top checkers. The temperature of the top checkers varies from about 700° C

to 1300° C. The lower checkers normally run from 450° C to 800° C, but have been known to reach 1300° C under abnormal conditions. It is evident that the lower checkers must have a high safety factor. Temperature fluctuations are not harmful to a silica brick as long as the lowest temperature reached is above approximately 400° C. For these reasons the Semet-Solvay practice, with use of silica for the top half of the checkers, seems very advantageous. Conductivity is also an important factor in a regenerator brick, and the greater conductivity of silica over clay brick gives an added reason for using as many silica checkers as possible. Strength is not an important factor and the brick need not be as hard burned as for other parts of the oven, provided room is left for expansion.

Regenerator Korbels.—The silica brick used in the korbel construction at the top of the regenerator chamber must be especially strong, but are not required to stand a very high temperature and are not subject to much temperature fluctuation.

Main Flues.—The main flues may run under the block as in Semet-Solvay ovens, or beside the block as in the Koppers design. It is Semet-Solvay's practice to make them of silica brick with a clay brick veneer. The clay brick absorbs the temperature fluctuations, due to reversing the draft, while the silica gives the necessary strength. The temperature is normally not over about 400° C, but a high safety factor is desirable.

Sole Flues.—Under the oven chamber comes the sole flue. In the modern Semet-Solvay regenerator oven, this is constructed entirely of silica shapes. It has to withstand nearly the same temperature fluctuations as the top checker brick of the regenerators, but at a slightly higher temperature. The silica must be well burned.

Division Walls.—Above the foundation walls in the Semet-Solvay oven come the division walls. These walls separate the oven chambers, making them independent of each other in heating, and carry the roof structure and charging car track entirely independently of the oven-heating flues. They act as huge reservoirs of heat, holding the flue temperature to a high

value when the oven is pushed and charged with fresh coal. The brick must be uniform in size, and high in strength and heat conductivity. Silica is used. It must be very well burned.

The Main Oven Chamber.—This requires great strength in the lining blocks, high burn and very good workmanship. The end blocks, *i. e.*, *jamb blocks*, of the oven lining should be of clay to withstand the sudden temperature changes due to raising the door for pushing. They must be very hard burned to resist abrasion.

Above the oven chamber there are about six (6) to nine (9) inches of silica, which has no particular requirements except a good burn. Then come several courses of "B" quality clay brick, several courses of red brick, with possibly some insulating brick, and then the paving brick. The brick on the face of the oven above the door present a special problem, as they are subjected to the hot gases from the oven during pushing, and to weather conditions—rain or snow—the rest of the time. They should be dense to resist weather and of open structure to resist spalling. A middle course must be steered between the two extremes. In several types of ovens there are special problems—such as gas nozzle brick, damper brick, and so forth, with which the writers have had no direct experience.

Description of Tests

The tests to which the refractories are subjected are as follows:

1. Inspection—size, warpage, ring, bond, vitrification.
2. Re-heating tests, "A," "R" and "B."
3. Fusion point.
4. (*a*) Bulk density; (*b*) Apparent density; (*c*) true density; (*d*) porosity.
5. Bending tests, "A," "R" and "B."
6. Load test.
7. Crushing and modulus of rupture.
8. Spalling test.
9. Fineness.
10. Plasticity.
11. Conductivity.

Sampling.—If sampling is done by a trained inspector, samples should be taken to represent the carload. In case there is doubt of the quality he should take about six to the car. He should estimate the per cent brick represented by the various samples, if there is a marked difference in quality. The factors to be taken into consideration are degree of burn, grind and workmanship. For an untrained workman, one sample per thousand chosen at random should be set aside, from every carload, for the trained inspector. From these samples a few should be selected by the trained inspector and sent to the laboratory for test; the number depending on the quality of the brick. In case of doubt, a large number should be tested.

1. Inspection.—This includes measurement for size, degree of warp, ring under the hammer test and any departure from standard samples in color, bond, vitrification or workmanship.

The following instructions for mason foremen and inspectors are based upon an extensive experience in the testing of this class of refractories.

HOW TO JUDGE FINISHED SILICA SHAPES AND BRICKS

1st Cracks.—Cracks are of two kinds, (1) "Surface Cracks" or so-called "Slick Cracks," due to drawing the slick over the ganister in the mould. These cracks are seldom over $^1/_{16}''$ in depth and are not dangerous. (2) Body cracks. These may develop in burning, particularly where there is a sharp re-entrant angle in the shape. Usually they may be found by careful inspection, but the surest method is to tap the brick or shape lightly with a light hammer. This test should always be used on bricks which go into important places in the oven, particularly when any cutting has to be done. Bricks should have a clear ring; those with punky sound should be rejected unless brick have been exposed to the elements, in which case the moisture would give them a dead sound.

2nd Dimensions.—Undersized silica brick are likely to be poorly burned. In this case they will show more expansion when brought up to heat in the oven than a full size brick. For instance, suppose a front slab of the oven lining is $^1/_4''$ short and in

order to make the cover brick lie flat, the back slab is trimmed 1/4″. On coming up to heat the front slab will expand 1/4″ more than the back slab and frequently break the cover brick. Undersized brick should only be used where expansion is unimportant. They do not conform to specifications and may be rejected. Oversize brick may be punky, due to too rapid burning. If the brick is solid and has a good ring, being oversize will not hurt it unless this means cutting. Cutting should never be done if it can be avoided, as it weakens the brick. Probably the labor is less in gaging and sorting brick than in cutting.

3rd Workmanship.—Uniformity in size, sharp edges and corners, friability and plane surface are important points to be considered. Three or four shapes set on edge dry, one on top of the other, gives a good idea of quality of workmanship.

4th Color.—The color of silica bricks depends upon the conditions of burning, the amount of lime used for bond and the amount of impurities. Color can not be used in comparing bricks made by different makers, but may be used with caution on bricks from a single maker. The best and hardest burn on eastern ganister will be white with red "splotches" or spots. Western and southern ganister is darker and harder and when well burned will be nearer a uniform color. A brick showing a rust brown color or fire flash is frequently cracked, more often the interior structure is shattered and unless they have a true, clear ring under hammer test, should in no case be used.

5th Iron Spots.—Iron spots will not cause any trouble when thoroughly oxidized unless the iron has eaten a large hole in the brick.

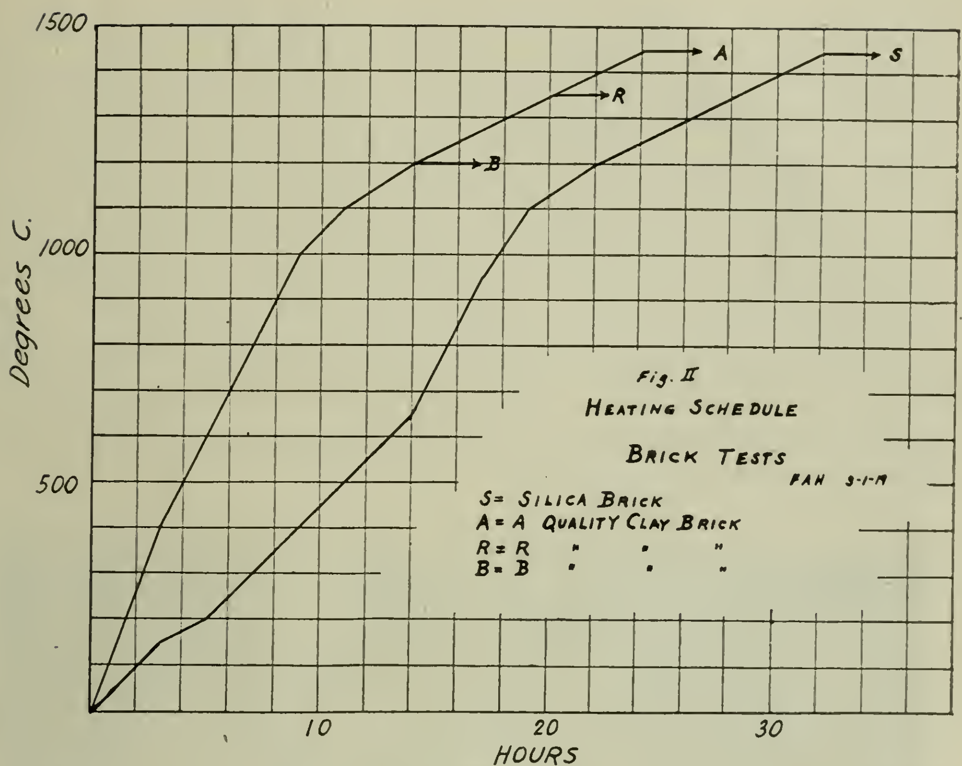
6th Density.—Laboratory tests may be made at the plant to determine approximately the degree of burn in case information is desired before tests can be obtained from the testing laboratory. Copies of the method for determining apparent density may be obtained from Syracuse.

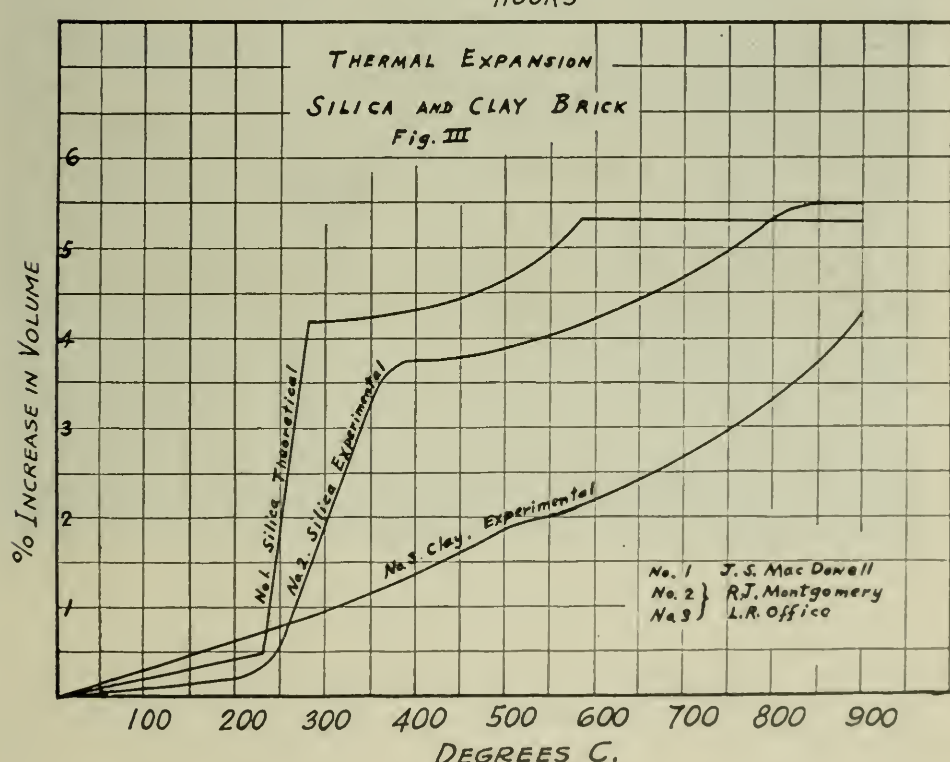
7th Laboratory Tests.—Other tests, such as reheating test, chemical analysis and porosity should be made at the testing laboratory if any question remains to be decided.

2. The Re-heating Test.—This is conducted in one of the four gas-fired furnaces shown in figure 1. When the samples have been selected for test, they are carefully examined for workmanship, ring and vitrification, if a clay brick. All dimensions are taken and the sample weighed. From these measurements the bulk density is calculated. The sample is then broken in half and on one piece linear measurements are made with a

FIG. 1.—Three of the large testing furnaces. No. 2 is fitted up for spalling tests.

vernier caliper or the volume determined by displacement. The half samples are set in the furnace and a diagram made showing the location of each sample as it is set. The gas is lighted and turned on gently. The temperature is controlled by hand regulation of the gas valve and the heating curve shown in figure II followed as closely as possible. These curves have been determined by long experience and represent the maximum safe speed for heating. Curves A, R and B give the schedule for clay


1500
1000
500
Degrees C.
10
20
30
HOURS
A
R
B
S
Fig. II
Heating Schedule
Brick Tests
FAH 3-1-19
S= Silica Brick
A = A Quality Clay Brick
R = R " " "
B = B " " "


Thermal Expansion
Silica and Clay Brick
Fig. III
% Increase in Volume
1
2
3
4
5
6
100
200
300
400
500
600
700
800
900
Degrees C.
No. 1 Silica Theoretical
No. 2 Silica Experimental
No. 3 Clay. Experimental
No. 1 J. S. Mac Dowell
No. 2 } R.J. Montgomery
No. 3 } L.R. Office

brick and S for silica brick. It will be noted that the rate of heating is about 50 degrees per hour until 650°C is reached, after which the rate is increased. Above 1100°C the rate is again slower, but this is merely due to the fact that the furnace will not conveniently heat much faster. The little slow up just before 200°C merely calls the attention of the operator to that particular point and insures careful heating from 200° up through the transition from alpha to beta Crystobalite (see Fig. III). Figure III is taken from data by Montgomery & Office, *J. Am. Ceram. Soc.*, and the calculation by MacDowell. It shows clearly the necessity of slow heating while the large volume change from 200° to 400°C is taking place.

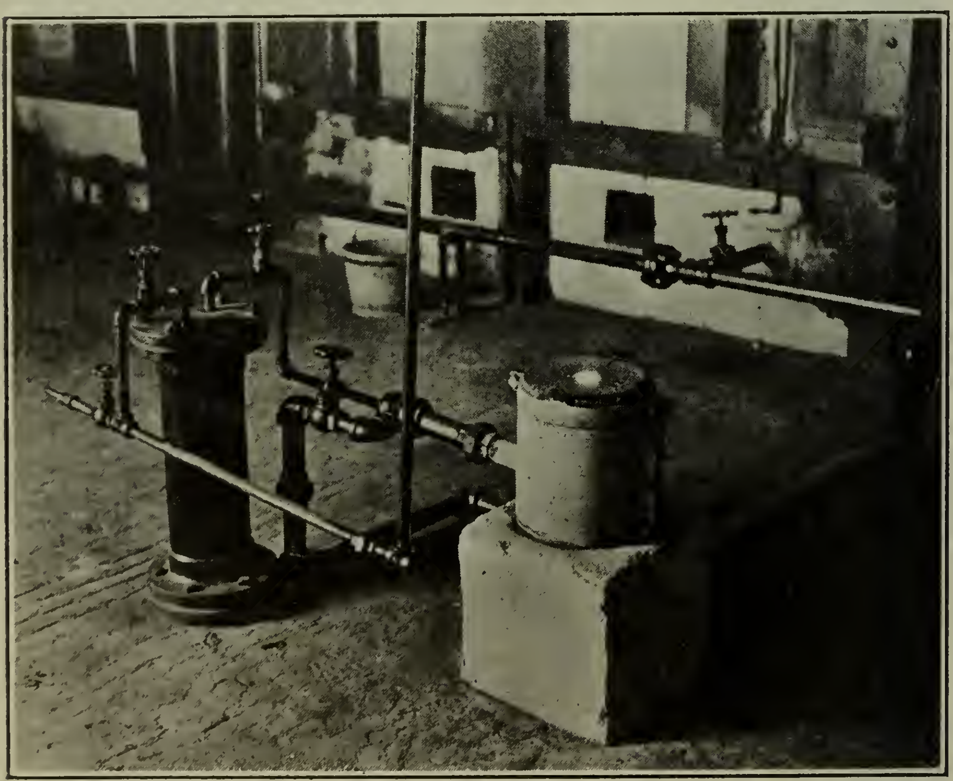


Fig. IV.—Pot furnace for fusion tests.

After reaching the maximum temperature, the temperature is maintained as nearly constant as possible for 72 hours. The gas is then shut off, the furnace kept closed and allowed to cool.

The door is cracked open at 18 hours for clay brick and not under 30 hours for silica, being opened wide six hours later. The temperature is recorded during the entire test by a recording pyrometer. It has not been possible so far to find a pyrometer tube impervious to gases which will consistantly stand 1450°C for 72 hours. For this reason two thermocouples are used. Two silfrax protection tubes are cemented into the back of the furnace, one above the other. The upper projects seven inches into the furnace chamber and the lower about two inches. A platinum thermocouple, in a fused quartz tube, is inserted in the upper tube and allowed to remain there ten minutes to get the actual temperature of the furnace. This couple is used for the first part of the heating-up period and two or three times during the test. A second platinumcouple in a vitrified porcelain tube is inserted in the lower silfrax sheath. This couple indicates a temperature about 100°C lower than the true temperature of the furnace. This is due to the fact that the silfrax sheath, which projects only a short distance into the furnace, carries heat away fast enough to keep it at a lower temperature than the hot gases, just as a fire-brick wall does not attain the temperature of furnace gases. The temperature is controlled by this couple, which also makes a continuous record of the temperature. The record by the upper couple amounts to a calibration of the lower couple during the run. The calibrating couple is kept in first-class condition by being frequently annealed. It is checked by comparison with a new couple or by taking the temperature of the brick while under test with a Leeds and Northrup optical pyrometer.

The furnace chamber is explored from time to time by means of the optical pyrometer, to insure its uniformity of temperature. Orton cones have also been used at times to check this point. Any variation in temperature is corrected by changing the holes in the gas burner pipe or altering the opening for waste gases in the floor of the furnace. The front row of bricks is always about 50°C lower in temperature than the others and for this reason a blank row on which no test is made is set in front. If the temperature goes wrong, the test is rejected.

After the furnace has cooled, the brick are removed and again measured with vernier calipers or by displacement. From the two sets of measurements, the per cent change in size is calculated. Typical reports are shown in Reports V and VI.

The "A" test is run at 1450°C, the "R" test at 1350° and the "B" test at 1250°C, each for 72 hours after attaining the full temperature.

3. **Fusion Point.**—This test is run according to the method C-24-20 of the American Society for Testing Materials. It is used on clay brick, silica cement, fire-clays and mortars.

4. **Density.**—Bulk density is determined as described above. It is of value in showing uniformity of product and to a slight degree gives an indication of spalling tendency. Apparent density is determined by the method described by Ross, and discussed in *J. Am. Ceram. Soc.* A vacuum of at least 20 inches of mercury should be maintained during the boiling. This can easily be done by means of a rotary oil (Cenco-Nelson) vacuum pump. A filter pump is not satisfactory. True density is determined in the usual manner, with the specific gravity bottle. Kerosene works better than water in the bottle, but this method has not yielded as consistent results as the apparent density. The apparent density method is very valuable in connection with silica brick. A study of this method is given below. Porosity is determined by method C-20-20, American Society for Testing Materials.

5. **The Bending Test.**—This test is used on clay brick for "A," "R" and "B" quality. In making this test the clay brick is supported on other brick, at both ends, seven inches in the clear, loaded with a five-pound cut fire-brick in the center, set on end. This test is conducted in connection with the reheating test and is run at the same temperatures and for the same length of time. This test is practically equivalent to the load test (No. 6) and need not be used where the load test is made. When a brick is being tested for shrinkage, it is usually convenient to run the bending test at the same time, otherwise the load tests saves time and gas.

6. The Load Test.—The test used is that described in Method C-16-20, American Society for Testing Materials.

7. Cold and Hot Crushing Tests and Modulus of Rupture.—These are conducted according to the standard methods.

8. Spalling Tests.—These are conducted according to the methods described by Howe and Ferguson. "A Study of Spalling" *J. Am. Ceram. Soc.* We prefer dipping in water to cooling by blast, as it is much easier to maintain standard conditions. an air

9. Fineness.—On fire-clay and silica cement *fineness* is of considerable importance. The test is made by sifting dry in a Ro-Tap Sieve-shaking machine for ten minutes. The automatic time stop and mechanical shaking give exact results if the sample is dry and the sieves standard and clean.

10. Plasticity.—To determine this we use a pail test. The cement or fire-clay is mixed up to the consistency of dipping mortar, and allowed to stand 24 hours. If after this time it has not settled so as to cake in the bottom of the pail, our experience shows that it will spread smoothly and easily and not give trouble by settling in the mortar boxes.

11. Conductivity.—Comparative tests have been made by building the roof of one of the test furnaces shown in figure I, the first of one kind of brick then of another, and measuring the temperature gradient through the roof at regular intervals during one of the "A" tests described above. This method is recognized as being very crude, but it has the advantage of duplicating actual operating conditions very closely for some cases.

Requirements and Specifications

All *silica brick* and shapes must pass the "A" reheating test, showing not more than 1.6% average permanent linear expansion. For regenerator checkers expansion up to 2% can be allowed. Lime content should not be specified until more complete data, on the effect of lime, are available. Alumina should not exceed 1.65%. For fineness of grind, 97% should pass a 1/4″ mesh screen. All Class No. 1 silica bricks should have a

modulus of rupture not less than 500 lbs. and cold crushing strength not less than 1600 lbs. per sq. in. Class No. 2, a modulus of rupture not less than 350 lbs. and cold crushing strength not less than 800 lb. per sq. in. Class 1 bricks should be used in bench walls, korbels, and oven linings. Shape brick should not have variations in dimensions greater than $^1/_{16}''$ to the foot for brick under 12″; and $^1/_8''$ to the foot for larger shapes. Visual inspection and the hammer test should eliminate cracked and badly warped shapes.

For *clay brick*, in the reheating tests "A," "R" and "B"—swelling must not be greater than 1%, nor shrinkage greater than 1.6%; bending tests not greater than $^3/_8''$ for "A" tests and $^1/_4''$ for "R" and "B" tests. Dimensions should not vary more than $^1/_8''$ from standard dimensions if under 12″, nor more than $^3/_{16}''$ to the foot if over 12″. In special cases one or more dimensions may be important or unimportant, in which case it may be shown on the shape B/P. When ordering brick, the purchaser should state whether hand-made or machine-made brick are desired, as the same clay mixture may give brick suitable only for very different service by the two methods of manufacture. "A" quality brick are used in boiler settings, stocker arches, etc. "R" quality brick for the lower deckers in the regenerators, main flue linings, sole flue or recuperator ovens and jamb brick. The "B" quality brick is used on doorlining shapes, for lower mat brick, top fill and oven face brick.

Silica cement must have a fusion point as high as cone 270 must all pass a 30-mesh screen on the fineness test; and must pass the pail test. It must not contain over 25% plastic clay.

"A" quality *fire-clay* must spread easily and smoothly with a trowel, all pass a 14-mesh and 95% a 20-mesh screen and fuse not lower than cone 28. "B" quality fire-clay may have a fusion as low as Cone 20. All "A" and "R" quality clay brick must be laid up with "A" quality clay. "B" quality clay may be used in laying up "B" quality brick.

Apparent Density and Permanent Expansion

The method given under (2) for testing silica brick gives very accurate and reliable results and has resulted in a large saving

of money for repairs. Figure V shows the difference which may exist between tile which are thoroughly burned and those underburned. In each case the lower part of the tile represents the tile as received from the manufacturer and the upper part a section which has been cut off and subjected to the reheating test. Note that number 1 shows practically no permanent expansion, while 2 and 3 show nearly $^1/_2''$ in 9 inches. Tile like number 3 failed repeatedly in the ovens. For the brick in the lower bench walls the importance of this point can not be overestimated. In a wall 38 feet to 40 feet long, with the brick laid almost end to end,

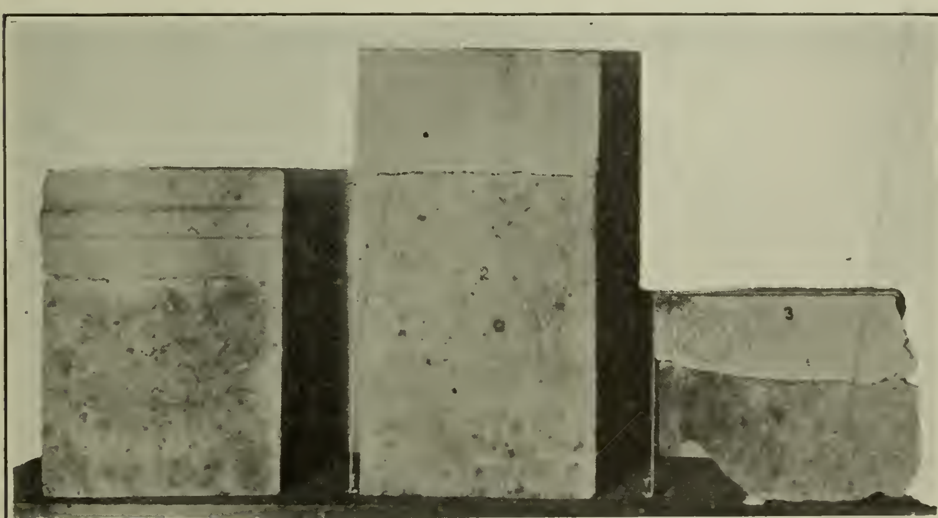


Fig. V—Showing expansion of brick on reheating test. Note that 2 and 3 expanded nearly $1\frac{1}{2}''$ while 1 remained practically unchanged.

a permanent expansion of two and one-half per cent means an increase in length of twelve inches. This increase does not take place all at once on starting the ovens, but is very slow. It lasts perhaps over ten years or more, at the low temperatures reached in this part of the oven. In spite of this low temperature the brick does grow. This gradual growth results in opening cracks in the upper structure which will eventually cause trouble. We have tested a number of brick which have been in service several years and never found any permanent expansion. The cracks may be closed by carbon deposits while the battery is in operation and yet make it impossible to start up again after

shutting down cold. In view of the great importance of the permanent expansion, and also the advantages obtained by a more rapid test than the reheating test, a large number of experiments have been made to obtain the relation between permanent expansion and apparent density. It was at once evident on starting the tests that a difference exists between the apparent density of brick made from Eastern, or Medina, and from Western, or Baraboo, quartzite. A difference also exists in the permanent expansion. After a large number of tests it seems probable that it is not commercially practicable to burn Western quartzite so that it has as little premanent expansion as the Eastern. Samples of Western bricks have been tested, however, which show the

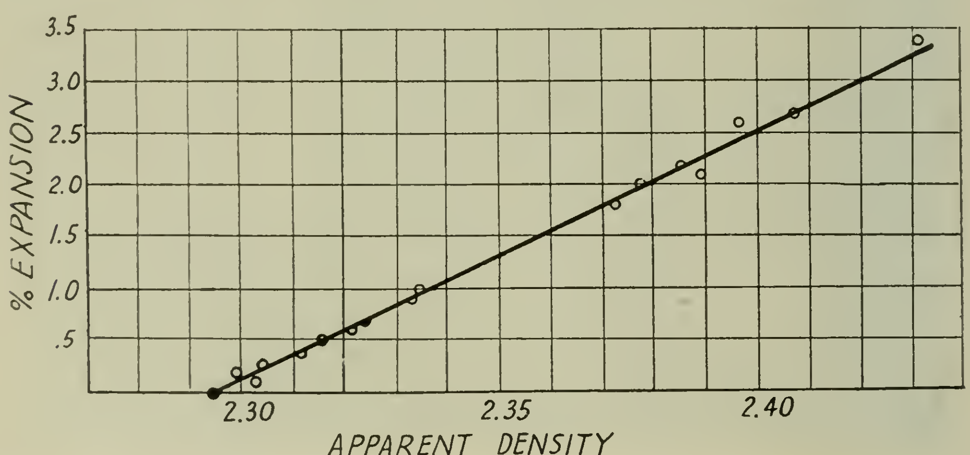


FIG. VI.—Pennsylvania silica brick; apparent density *vs.* per cent expansion on reburning test.

same apparent density as Eastern bricks. There have been only some half dozen samples out of about a hundred for which this is true. These same six samples show almost no permanent expansion. In connection with the work of the Committee on Refractories for American Society for Testing Materials, a number of green brick were obtained and burned in our testing furnaces. A temperature and time which leaves no permanent expansion in Eastern bricks leaves nearly 1 per cent in the Western bricks. The apparent density of the Western brick could not be brought down to the same value as the Eastern by three burns in some cases. Figure 6 gives the relation between ap-

Column 1	Column 2	Column 3	Column 4	Column 5
A	1.0	2.374	2.334	.040
A	.0	.345	.334	11
A	.0	.373	.334	39
A	.0	.341	.334	07
B	.2	.364	.343	21
B	.2	.372	.343	29
A	.3	.345	.347	+02
A	.3	.369	.347	22
B	.4	.362	.351	11
A	.5	.390	.355	35
A	.6	.368	.360	08
B	.8	.385	.368	17
A	.8	.396	.368	28
B	.9	.384	.373	11
A	2.0	.370	.377	+07
A	.1	.429	.382	47
A	.2	.414	.386	28
B	.5	.436	.399	36
C	0.2	.308	.302	06
C	.4	.328	.310	15
B	.4	.329	.310	18
C	0.5	2.329	2.314	0.015
C	.6	.331	.319	12
B	.8	.327	.327	00
B	.8	.332	.327	04
B	1.2	.350	.343	07
B	.2	.346	.343	03
B	.8	.387	.368	19
B	.8	.396	.368	28
B	.9	.387	.373	14
B	.9	.372	.373	+01
B	2.0	.397	.377	20
B	.0	.385	.377	08
B	.0	.392	.377	06
B	.2	.408	.386	22
B	.2	.420	.386	33
B	.3	.416	.390	26
B	.3	.388	.390	+02
B	.3	.396	.390	06
			Average	0.016

parent density and permanent expansion for bricks from eastern quartzite. It seems to be quite accurately a straight line. A few values obtained fell clear off the line, but they were so few in comparison with the total number that they were certainly due to experimental error. Some of the points shown on the diagram represent average density for eleven bricks, all of which showed the same permanent expansion. The curve represents the results of about 150 determinations. In order to find the difference between the Eastern and Western density, the following table was made. The first column gives the manufacturer; the second the permanent expansion on the reheating test; the third the apparent density; the fourth column gives the apparent density of an Eastern brick with the same amount of permanent expansion and the last column gives the difference between the Eastern and Western densities.

The average difference is 0.016 for the thirty-nine determinations.

By the second method, burning the green brick from Eastern and Western manufacturers, the average density of thirteen Eastern brick was 2.306, and for twelve Western brick was 2.339, the difference being 0.033. After repeated burnings of three Western brick, the average density decreased to 2.320, a decrease of 0.019. The average density of four Western brick burned in an Eastern kiln, was 2.340, while the average of the Eastern brick burned under the same conditions was 2.31 to 2.32.

The general conclusion is that the apparent density of Western brick, which it is practicable to reach, is from 0.016 to 0.02 higher than that of Eastern brick. Equal densities mean, however, that the same amount of permanent expansion will eventually come out of the brick, if the service is long enough.

In conclusion, we wish to acknowledge the fact that the reheating tests and bending had their original development under Dr. L. C. Jones, Chief Chemist of the Solvay Companies and that to him is due the principle which underlies, *viz.*, that a long period of heating is necessary to develop the qualities of a clay brick.

United States Refractories Corporation
and Semet-Solvay Company

Discussion

DONALD W. ROSS: The data of this paper are apparently in entire agreement with the following data of the U. S. Bureau of Standards Tech. Paper 116, notably figures 16 17, 18, 19, 20 and 21, and tables 7, 8, 16 and 18. The 1500°C data of table 7 of the latter bear out the data of figure xl of the present paper and the writer believes the method used in plotting the results shown in this figure is unique. Such a method of plotting the results has the advantage that the relation between specific gravity and the permanent increase in exterior volume of commercial silica brick occasioned by heating them sufficiently to cause the remaining quartz to be transferred to the lower specific gravity forms is apparent at a glance. The authors state that the curve as shown is obtained largely from data of tests on brick made from Medina quartzite. Our own data (referred to above) indicate that by a given heat treatment the quartz contents of brick made from Baraboo quartzite are less transformed to low specific gravity forms than are those of brick made from Medina quartzite. We further found that brick made of friable quartzites or those high in fluxes, other than iron, are, on firing, apt to result in a very porous product, which shows an excessive exterior volume expansion. Materials of this latter type could hardly be expected to conform to the curve shown in figure 11. However, such materials are easily identified by their friableness.

It seems worthy of note that from the transverse strength data of Tech. Paper 116 (Table 21), 500 pounds per square inch was arrived at as a desirable value for minimum strength of heavy duty brick and that from entirely different data and working separately, the authors have arrived at the same value.

With reference to the percentages of fluxes permissible in silica brick, the writer believes we will do wisely by adhering to McDowell's[1] limits—for quartzite 96 to 98 per cent SiO_2, combined percentages of iron and alumina 2.5 per cent, and less than 0.5 per cent alkalies, for the limits for CaO in the fired brick set at from 1.5 to 3.00 per cent.

[1]McDowell, J. S., "A Study of the Silica Refractories," *Am. Inst. of Mining Engineers*, Bull. 119, 2009.

Baraboo brick sample number 18, table 16 of Tech. Paper 116, which received 9 years service in a by-product coke oven, had the unusually low porosity of 19.94 per cent. It seems probable that with bricks from the slow transforming Baraboo quartzite trouble caused by expansion in use due to further transformation of quartz to low specific gravity forms, may be at a minimum, and that with very slow transformation in extended service there may be a slight decrease in porosity, thus in part offsetting the increased value of the silica and tending to further minimize this danger.

The heating schedules (Figs. 2 and 3) shown in the present paper in conjunction with the method of measuring the flow of the heat through crowns, should be of interest to persons using glass tanks which have silica crowns. For such heating curves in conjunction with the conductivity of silica brick and similar information for clays brick should eventually lead to the establishment of a minimum safe rate heating schedule for such tanks.

CERAMIC ABSTRACTS

Author Index to Abstracts for June

General and Miscellaneous

1. **Drying by electrically superheated steam.** J. Karrer. *Engineering*, **110**, 821–2 (1920).—Owing to the scarcity of coal in some sections of Europe during the war it was found profitable to use electricity as the source of heating energy in drying. In the method described, the air in the oven chamber is kept circulating by fans, and the water vapor driven off from the material is superheated; greater thermal efficiency was obtained than by drying with hot air. Excellent results were obtained in the drying of *foundry molds and cores*, and in drying peat and vegetables; vegetables dried in this manner retain their natural color. Donald W. MacArdle. (*C. A.*)

2. **Diatomaceous earth.** Norris Goodwin. *Chem. Met. Eng.*, **23**, 1158–60 (1920).—A resumé of the history, occurrence, properties and uses of diatomaceous earth, accompanied by an extensive bibliography.

W. C. Ebaugh. (*C. A.*)

3. **Permutite.** H. Vogtherr. *Z. angew. Chem.*, **33**, I, 241–3 (1920).—A general review of the history and development of base-exchange processes. V. concludes that the active exchangeable bases are imbedded in the porous structure of the zeolites, in whose fine capillaries the exchange action takes place. The silicate itself, whether composed of silica alone or in combination with alumina or iron oxide, does not play any function in the exchange of bases except to furnish a medium of suitable physical nature. Methods of prepn., and phys. and chem. properties are given. Patents are referred to.

G. C. Baker. (*C. A.*)

4. **Talc and soapstone.** R. B. LADOO. *Eng. Min. Jour.*, **111**, 161 (1921).—A short resumé of the talc industry in 1920. D. D. SMYTHE.

5. **The mica industry.** J. V. LEWIS. *Eng. Min. Jour.*, **111**, 158.—A short resumé of the mica industry in 1920. D. D. SMYTHE.

6. **Barite.** J. B. PIERCE, JR. *Eng. Min. Jour.*, **111**, 155.—A short resumé of the barite industry in 1920. D. D. SMYTHE.

7. **Monazite.** H. C. MEYER. *Eng. Min. Jour.*, **111**, 158.—A short resumé of the monazite industry in 1920. D. D. SMYTHE.

8. **The domestic talc situation.** ANON. *Eng. Min. Jour.*, **111**, 313.—A short general discussion of the United States talc industry in 1920 based on statements of R. B. Ladoo of the U. S. Bureau of Mines. D. D. SMYTHE.

9. **The non-metallic mineral industries of the United States.** R. B. LADOO. *Eng. Min. Jour.*, **111**, 215–221.—A general discussion emphasizing the importance of the non-metallic mineral industries of the United States.
D. D. SMYTHE.

PATENTS

10. **Vesicular materials and compositions.** C. W. BOYNTON. Brit., 153,030, Apr. 16, 1919. A cellular product which is of low apparent sp. gr., a non-conductor of heat and electricity, free from laminations, and substantially impervious to H_2O is obtained by reducing *clay or shale* to a uniformly fine condition, and treating it in a dry, plastic, or slurry state under gradually increasing temp. until the mass softens and swells owing to the generation of gas from some of its constituents. A suitable clay contains SiO_2 49 parts, Al_2O_3 21 parts, Fe_2O_3 11 parts, C 2 parts, and negligible quantities of CaO and MgO. Generally, the clay or shale should be rich in metallic oxides, compds. of C, S, Na, K, or the like, the nature and proportions of flux and gas-generating ingredients being preferably such that the material softens at the same temp. as the gas is generated. Additions or subtractions may be made to ensure this. Excess of Fe, CaO and MgO should be avoided. The material is ground and may be used dry, or as slurry, or it may be made into a plastic mass and molded, in which case it is advisable to preheat the articles to drive off superfluous H_2O. The temp. of burning varies; it may be as low as 1040°. If the product is to be used for insulation or as an aggregate for concrete, oxidation of the surface during burning should be avoided. The product may be preformed into slabs, tiles, or the like or crushed and added to cement. The invention is distinguished from those in which clays, shales, slates, and the like are heated to produce porous masses. (*C. A.*)

11. **Treating clay.** P. SCHIDROWITZ, W. FELDENHEIMER and W. W. PLOWMAN. Brit. 153,861, June 2, 1919.—A process for the treatment of clay comprizes suspending the clay in H_2O with the aid of a deflocculator such as Na_2CO_3 and then, before any settlement takes place, evapg. the whole suspension to dryness. The clay may be first mixed with sufficient H_2O to give a pasty mass and then sufficient deflocculator added to produce fluidity, with

or without further addition of deflocculator until the fluidity decreases; or the clay may be directly worked up with H_2O and deflocculator. The clay may be first purified, *e. g.*, by one of the processes described in 106,890 (*C. A.*, **11**, 2607) or 121,191 (*C. A.*, **13**, The 647). product may be used for incorporation with rubber. (*C. A.*)

Apparatus and Instruments

12. A new study of the leucoscope and its application to pyrometry. IRWIN G. PRIEST. Bur of Standards. *J. Optical Soc. Am.*, **4**, 448–95 (1920).—The leucoscope is an app., originally suggested by Helmholtz, in which, by polarization, the entering light is sepd. into 2 complementary parts, which can be made equal in their effect on the eye, and therefore of the same color as the original. For white light one complementary part will contain mainly yellow and blue, the other red, green, and violet. In practice the match is not perfect; one complementary is yellowish, the other bluish, but they can be made equally red. The necessary division of the light depends on the spectral sensitivity curve of the eye; when the character of the light changes, the setting of the instrument will have to be changed to make a match. The leucoscope can thus measure *color temp.* and can be used as an *optical pyrometer* which requires no auxiliary app., either elec., or a comparison source of light. Priest refers to an article by Koenig (*Ann. Physik.*, **17**, 990 (1881)) for a description of the instrument; he reports a test of its efficiency He finds that there is a difference in the readings of diff. observers, but the calibration curve detd. for any one does not change appreciably, not even when the observer is feeling unwell; the av. agreement reached with an imperfect instrument is about 15° at 2000°K., and better at lower temps., though over 100° at 5000°. The instrument was further studied, as well as its application in finding the color temp. of light sources, illustrated by daylight.

W. P. WHITE. (*C. A.*)

13. Note on the measurement of the density of minerals. L. H. ADAMS. Geophys. Lab., *Am. Mineral.*, **6**, 11–12 (1921).—The marked advantages of a *flat-top pycnometer* for measuring ds. are pointed out, and brief details of manipulation given. The wt. of the app. filled with liquid can be detd. to within 0.1 mg., which implies an accuracy of about 0.0001 in the d. of an ordinary solid. E. T. WHERRY. (*C. A.*)

14. Reversible mercury manometer with dampened oscillations. PIERRE MENARD. *Compt. rend.*, **171**, 1129–30 (1920). D. W. MACARDLE. (*C. A.*)

15. Separation of slimes from liquids by centrifuging. BERTHOLD BLOCK. Charlottenburg. *Chem. App.*, **8**, 3–5 (1921); 3 cuts.—This is the 5th supplement to B.'s article (*C. A.*, **14**, 1872) in which he considers "the combination of the unperforated centrifugal drum with a filter." J. H. MOORE. (*C. A.*)

16. The technic of the filtering drum. LEONCE FABRE. *Industrie & chimique*, **7**, 346–9 (1920).—A description of the construction and method of

operation of the Zenith filter, and of the advantages which it presents in filtering slurries in the chem. industries (caustification of Na_2CO_3, manuf. of $NaHCO_3$, cement ind., etc.). A. P.-C. (*C. A.*)

17. Static notched-bar testing machine. ANON. *Chem. Met. Eng.*, **23**, 1180 (1920).—If a notched bar specimen is broken slowly by static pressure the work expended is comparable to that measured by a dynamic impact machine, and is much more effective in distinguishing between brittle and ductile metals. J. C. W. Humphry's app. operating on this principle is described and illustrated. By its use a curve is obtained plotted in foot-pounds and radians as axes, and the total energy absorbed in breaking the test piece can be calcd. from the graph, or can be obtained automatically by an integrating device fitted to the machine. W. C. EBAUGH. (*C. A.*)

18. Distance-reading thermometer. ANON. *Engineering,* **110,** 736–7 (1920).—An instrument of great accuracy constructed by Messrs. Negretti and Zambra of London. Errors due to temps. of the capillary connecting the bulb with the indicator are eliminated by making the capillary of material of high expansion and running throughout its length a wire of material of low expansion. The space not occupied by the wire contains the working liquid, and the vol. of the wire and liquid and the capacity of the tube are so calcd. that for a given change in temp. the change in vol. of the liquid is the same as the change in space it can occupy. The indicator is a Bourdon gage with all gears and levers eliminated, and having a bimetallic strip to compensate for variations in its temp. The error due to the height of the bulb with respect to the indicator is eliminated by a device for adjusting the zero.

G. W. STRATTON. (*C. A.*)

19. A substitute for Thoulet's solution. A. THIEL AND L. STOLL. Marburg. *Ber.*, **53**, 2003 (1920).—In the detn. of d. by the method of suspension, the aq. solns. most used are those of potassium mercuric iodide (Thoulet), and barium mercuric chloride (Rohrbach). The authors propose the use of $Pb(ClO_4)_2$ in place of these. The soln. is prepd. by treating perchloric acid with Pb carbonate and warming. The satd. soln. at 15° contains about 78% of $Pb(ClO_4)_2$, and its d. can be found accurately to the third decimal place with a Westphal balance. The d., 2.6, is not such as to make this soln. a complete substitute for the others, yet it covers a wide range and is relatively cheap. R. E. HALL. (*C. A.*)

PATENTS

20. Silica-washing apparatus. R. H. MOORE. U. S., 1,366,582, Jan. 25. The app. is adapted for washing a mixt. of silica 65 and clay 30 parts to obtain nearly pure silica. (*C. A.*)

Refractories and Furnaces

21. Swedish electric pig iron furnace. JONAS HERLENIUS. *Chem. Met. Eng.*, **24,** 108–12 (1921).—The furnace consists of a wide melting chamber or crucible above which is a shaft with a bell-charging apparatus at the top.

The shaft is designed in accordance with the general practice for common blast furnaces except for a recent tendency to widen out the lower section, making the diameter of the shaft at its junction with the crucible even larger than at the bosh. The entire *brickwork* and shell-plate of the shaft are *suspended independently of the crucible* and make a flexible, water-cooled joint with the roof of the crucible. The shaft is lined with fire-brick to a thickness of 18 in. for the upper and middle sections and about 14 in. for the lower. The crucible is cylindrical and is usually lined with fire-brick, although rammed-in coke and waste electrodes have been used with success. The crucible roof is of fire-brick of special shape. Through this roof the electrodes are inserted at an angle of 65° with the horizontal. A portion of the waste gas taken from openings in the throat is returned to the furnace and forced into the space between the charge and the roof through tuyères which point upward to blow the gas directly underneath the roof in order to cool it. The vol. of the circulating gas is const., so the gas formed during the process is available for auxiliary heating. This gas has a high B.t.u. value (258 B.t.u. per cu. ft. dry gas). The electrodes are of amorphous C, 4 to 8 in no., round (24 in. in diameter), and jointed for continuous feed. Electrode consumption has varied from 11 to 19 lbs. per ton of pig produced. As the power input is regulated by changing the transformer voltage, there is no need for electrode adjustment, except as they are consumed. The electrode holders, elec. contact clamps, the flexible joint between shaft and crucible, the tap-hole, and the tuyères are all water-cooled. There is a water-spray device for the entire shell of the crucible and the crucible roof is cooled by an air blast. The necessary elec. equipment is described. The transformer secondary voltages required for operating are 55–110 v. for charcoal or 35–70 v. for coke furnaces. There are installations operating on 25- and 50-, as well as 60-cycle a. c. In starting the furnace it is preheated for 2 to 3 weeks with a wood or coke fire in the crucible. Then 2 to 3 tons of coke and about 20 charges of coke, ore, and lime are shoveled into the crucible through the electrode holes and the electrodes inserted. The shaft is filled with mixed ore, lime and coke, and finally with charcoal with slowly increasing ore content. The current is then switched on, but the gas circulation is not started until about 2 days later. The charges contain 50–60% of Fe. The consumption of charcoal amts. in general to only 35–40% of the requirement in a common blast furnace. During 1918 the av. consumption of charcoal in all Swedish blast furnaces was 55.6 hl. per ton of pig, whereas in the elec. pig-Fe furnaces it amounted only to 24.8 hl. per ton. Few data are available as to the operation of these furnaces on coke (Stig, *C. A.*, **14**, 2752). Elec. pig-Fe is more thoroughly deoxidized than pig from the common blast furnace and, therefore, requires less Si and Mn to be suitable for the open hearth. Fe and slag are tapped from the elec. furnace at a lower temp. than from the blast furnace, but with an ample power input the temp. can be increased. There is no trouble in producing a pig high in C and Si and with a gray fracture. Desulfurizing in usual practice is less than in the ordinary blast furnace, owing to the lower temp.

This is overcome in recently installed high-power furnaces. About 2600 kw. hrs. are consumed per metric ton of pig-Fe produced. L. JORDAN. (*C. A.*)

22. Heat modifies acid furnace reaction. J. W. GALVIN AND C. N. RING. *Foundry*, **49**, 72–4 (1921).—The acid elec. steel furnace in foundry practice is considered. The efficiency of the furnace depends largely on the method of building up the bottom and the shape of the bottom. It should be burned in layer by layer and should have steep sides (cup-shaped rather than saucer-shaped) in order that the charge, both before and after melting, may be more directly under the arcs and subjected in larger part to direct flow of the current and, therefore, heated by internal resistance of the metal rather than by radiation from the arc and conduction from the center of the bath alone. Time and current can also be saved by using scrap that forms a compact mass. When such scrap is not available it is of advantage to leave some liquid metal in the furnace after each run and as quickly as possible throw in the new charge. The whole mass will then tend to weld into a solid body. After the charge is molten the slag should be kept thin by the addition of small amts. of Fe-ore from time to time. The control of the Si content of the product of the acid elec. furnace is most difficult. At the temp. of the open-hearth furnace SiO_2 is not reduced by C, but at the higher temp. of the elec. furnace this reaction does take place and the Si is absorbed by the metal bath. It is probable that Fe also has a reducing effect on SiO_2 under these conditions. This trouble is avoided and oxidation of the metal is kept down by holding the temp. of the metal to open-hearth temps. until the furnace reactions are as nearly complete as possible and then rapidly increasing the temp., and tapping at once before the high temp. reactions have time to go very far.

LOUIS JORDAN. (*C. A.*)

23. Possibilities of gaseous heating. W. N. BOOTH. *Gas J.*, **153**, 223–7 (1921); *Gas World*, **74**, 77–8 (1921).—The utilization of gas in relation to industrial furnace heating is discussed. Theoretical consideration is given to such problems as calorific intensity of various fuels and its relation to the thermal efficiency of a furnace, and loss of heat through furnace walls and its prevention. Thermal efficiencies of furnaces have been very low, av. only about 18 to 20%, but improvement is being made and efficiencies of 50% are predicted. J. L. WILEY. (*C. A.*)

24. The development of the vertical (gas) furnace. F. DOLLE. *Het Gas*, **40**, 207–11 (1920).—Summary. NATHAN VAN PATTEN. (*C. A.*)

25. A novel core oven. STEPHEN B. PHELPS. Pittsburgh. *Metal Ind.*, **18**, 503 (1920).—Instead of using the usual track to support the core trucks, "I" beams and trolleys were used to support them from overhead. This arrangement removed the supporting elements from the zone of most intense heat. The ends of the trucks were made as oven doors so that when one truck was drawn out for reloading, the back end of the truck acted as a door and closed the oven, permitting access to one truck while the cores on the other truck were baking. A. W. OWENS. (*C. A.*)

26. Steel, sand properties. R. L. Lindstrom. *Foundry*, **48**, 940–3 (1920).—Lab. tests should precede large purchases of sand or clay for steel foundry purposes. Both sand and clay should be of the same high quality. The ideal *clay* will have both high bonding power and a high softening point. For the bonding tests 10% clay is mixed with 90% of a good sand and with enough water so that the mixt. will just adhere to the palm of the hand. Knead for exactly 2 min. and age in a covered receptacle for 12 hrs. A block 1 by 1 by 12 in. is made under uniform pressure and is pushed lengthwise over the edge of a glass plate until it breaks off. Considering 3 in. as 100, the length breaking off is the bonding strength. The following specifications will designate a good clay: bonding strength 85, softening point 1600°, fineness test, not more than 5% shall remain on a 20-mesh sieve and not less than 75% on a 100-mesh. A good sand will be high in silica (97–99%); 85% should be retained on the 20-,40-,and 60-mesh screens and the grains should be well rounded. A. W. Owens. (*C. A.*)

27. Converting high-grade mat in magnesite-lined converters. H. C. Robson. *Bull. Inst. Mining Met.*, **1920**, No. 194, 10 pp. (*C. A.*)

28. Méker burners and Méker furnaces (gas) for industrial purposes. Stavorinus. *Het Gas*, **40**, 214–8 (1920).—A discussion of the use in the industries, chiefly metallurgical, of Méker burners and furnaces.

Nathan Van Patten. (*C. A.*)

29. Heating-furnace fuel progress during 1920. A. E. Blake. *Blast Furnace & Steel Plant*, **9**, 179–80, 18 (1921). E. J. C. (*C. A.*)

30. Foreign graphite in 1919. Arthur H. Redfield. U. S. Geol. Survey, *Mineral Resources of U. S.*, **1919**, Part II, 181–210 (preprint No. 12, published Feb. 5, 1921). E. H. (*C. A.*)

31. Fuel saving by furnace efficiency. Sydney N. Duguid. *Chem. Age* (London), **3**, 592–3 (1920).—See *C. A.*, **14**, 3778. (*C. A.*)

32. Glory holes and magnesite. R. A. Bankson. *Eng. Min. Jour.*, **111**, 49–52 (1921).—Prior to the war our supply of mag. was obtained from Austria. At the outbreak of the war this supply was cut off and a scramble took place to find domestic mag. The two principal sources found were in Calif. and in Wash., but since the Calif. material is amorphous, only the Wash. deposits furnished material suitable for refractories. As the price rose two important concerns and numerous smaller operators started to mine and burn mag. From a max. of $160 at the time the armistice was signed, the price dropped $80 in a day and thus forcing many of the smaller operators to drop out. Shortly after a third concern, the American Mineral Production Co., entered the field and is now in competition with the first two companies in the fields. The A. M. P. C. owns the Austrian deposits and so, due to the fact that it is trying to block the protective tariff, the rival companies claim

that it is trying to discredit the Amer. deposits. Since the demand is limited and cannot be increased it is a question as to whether Amer. deposits or Amer. owned foreign ones will supply the market. The older companies ask for a tariff of $15 a ton and even with that they claim that the Austrian mag. is cheaper, and that without it the Amer. mag. industry will be doomed and their equipment and property rendered worthless. The A. M. P. C. state that a protective tariff is unnecessary at the present time since the Austrian mag. costs them more to produce than the Amer. After two years, it is claimed, conditions will probably be such that the tariff question can be definitely decided. They also state that the tariff will affect them equally with the other companies since they intend to fully develop their Amer. supply. A possible outlet for the Amer. mag. is through the manufacture of plastic magnesite. One of the older companies has just completed a furnace for the production of this material.

33. **Magnesite.** R. W. Stone. *Eng. Min. Jour.*, **111**, 158 (1921).—A short résumé of the magnesite industry in 1920.

34. **Graphite industry.** B. J. Miller. *Eng. Min. Jour.*, **111**, 157 (1921). A short résumé of the graphite industry in 1920.

35. **Bauxite and aluminum.** J. M. Hill. *Eng. Min. Jour.*, **111**, 155–156 (1921).—A short résumé of the bauxite industry in 1920.

36. **Zirconium. Uncommon ores and metals.** H. C. Meyer. *Eng. Min. Jour.*, **111**, 150–1 (1921).—A short résumé of the zirconium industry in 1920.

37. **Chromite.** S. H. Dolbear. *Eng. Min. Jour.*, **111**, 147.—A short résumé of the chromite industry in 1920.

38. **The uses of graphite.** Consultation. *Eng. Min. Jour.*, **111**, 430 (1921).—A short discussion of the uses of graphite. D. D. Smythe.

39. **Why Washington magnesite mines shut down.** R. W. Stone. *Eng. Min. Jour.*, **111**, 464 (1921).—The three companies producing magnesite in Stevens Co., Wash., have suspended operations almost completely. It is claimed that the shut-down is due to the importation of Austrian magnesite but statistics show that the imports form only 18% of the magnesite consumed in 1920. The more probable reason is lack of orders from the steel companies as many steel plants are now idle.

40. **Graphite production in Madagascar at a standstill.** Anon. *Eng. Min. Jour.*, **111**, 378 (1921).—In the Commerce Reports of the French Ministry of the Colonies it is stated that due to present business conditions the operation of a number of old deposits has ceased and no new ones have been opened in the graphite districts of Madagascar.

41. **Chromite deposits of Bahia, Brazil.** H. E. Williams. *Eng. Min. Jour.*, **111**, 376–8 (1921).—Some years before the war chromite was discovered

at Santa Luzia, 303 km. by rail from the city of Bahia. A large amount of ore was extracted during the war but since then the mines have been idle. The country rock consists of a fine-grained quartzose gneiss cut by dikes of pegmatite. The chromite occurs as lenses in the gneiss. D. D. SMYTHE.

PATENTS

42. Alumina. S. E. SIEBURIN. Brit., 153,500, Jan. 19, 1920. Al_2O_3 is prepd. from a HCl soln. of any aluminous material by calcining the crystals of $AlCl_3$ obtained by satg. the soln. with the gaseous HCl resulting from a previous calcination. The $AlCl_3$ is calcined in a continuously working furnace, consisting of several stories, each of which is provided with an outlet, and the gases evolved from a particular batch are not conveyed to the $AlCl_3$ soln. until they contain sufficient HCl. When an ordinary type of furnace is used, the issuing gases are passed through a condenser, in the first chambers of which a watery soln. of HCl is formed while acid substantially free from H_2O remains uncondensed and is conveyed to the saturator. (*C. A.*)

43. Zirconium salts. H. WADE. Brit., 153,113, Aug. 8, 1919. A new basic sulfate of Zr of the compn. $5ZrO_2.3SO_3.13H_2O$ free from Fe, Ti, and Si is obtained by adding H_2SO_4 in the requisite quantity to a soln. of Zr oxychloride containing free acid, preferably HCl. The basic sulfate is pptd. on heating. (*C. A.*)

44. Aluminothermic production of zinc and corundum. KOHLE und ERZ G. m. b. H. Ger., 319,814, May 8, 1917.—An intimate mixt. of Al, ZnO of a high degree of purity, and Zn dust is subjected to the aluminothermic process. The Zn dust is added in such amt. that the speed of the reaction is regulated, and the excess heat of the reaction is utilized. The Zn vapor may be condensed, and the Al_2O_3 obtained as a high-grade *corundum*. The excess heat is used to melt down the otherwise difficultly melted Zn dust. (*C. A.*)

Chemistry, Physics and Geology of Raw Materials

45. Determination of ferrous and ferric oxide in acid open hearth slag. GEORGE T. DOUGHERTY. *The Chemist-Analyst*, **32**, 18 (1921).—Place in a 60 cc. lead test tube 1/2 gr. finely ground slag and 5 cc. water. Heat gently in current of CO_2 until oxygen is removed. Then remove stopper, add 5 cc. HF and 10 cc. 1-1 H_2SO_4, replace stopper and start current of CO_2 gas and continue heating gently for 30 minutes. Remove test tube from source of heat, add 25 cc. cold H_2O, stopper and immerse tube in cold water. Transfer contents of tube to casserole containing 250 cc. water, 15 cc. 1:2 H_2SO_4 and 5 g. boric acid. Stir and titrate with standard $KMnO_4$. Compute FeO. Decompose a second sample of material in platinum in the same way and reduce with stick of zinc. Add 4 g. boric acid and titrate with $KMnO_4$. Compute total Fe and then Fe_2O_3 by diff.

46. Decomposition and analysis of silicates without the necessity of fusion. HERBERT E. ZSCHIEGNER. *The Chemist Analyst*, **32**, 21 (1921).—This method

was successfully used in the analyses of fused magnesia and should be applicable to many compounds of Mg, Ca, Si, Fe and Al. Digest 1 g. of finely powd. sample with 1-1 HCl, dilute with equal vol. hot water, filter and wash residue three times with hot water. Evap. filtrate to dryness twice with HCl. Warm residue with 5 cc. water and 2 g. KOH. The silicates decompose forming soluble K_2SiO_3, at the same time liberating any mechanically enclosed Fe, Mg, and Ca oxides. Acidify the KOH solution with HCl and evap. to dryness twice. Combine with residue from filtrate, dissolve in hot water and HCl and filter through same filter. The remainder of the analysis proceeds by customary methods.

47. Acidity of Japanese acid clay. KIUHEI KOBAYASHI. *J. Chem. Ind.* (Japan), **23**, 543–9 (1920).—Japanese acid clay (Japanese fuller's earth) has the compn. $Al_2O_3.6SiO_2.H_2O$, and is probably a mixt. of colloidal hydrous Al silicate ($Al_2O_32SiO_2H_2O$) and an amorphous compound of ortho-silicic acid ($SiO_2.H_2O$) containing certain basic compds. as impurity. The reason why this clay should give an acid reaction was investigated by K., who found *no true acid substance in the clay* itself. The conclusion is that the acid reaction on blue litmus paper or other indicators is due to free mineral acid liberated by adsorptive action of this clay. When it is added to some basic dye (R-Cl), then there may be supposed the existence of a so-called Helmholtz's double layer on the surface of the clay and that the clay adsorbs OH^- according to its property as an acid gel, H^+ being thus liberated. R. combines with OH^- and H^+ unites with Cl^- of the dye. In a similar manner, when the acid clay is added to neutral KCl soln., it adsorbs K^+, and HCl will be formed, which in turn dissolves Al of the clay. Subsequently $AlCl_3$ is hydrolyzed to $Al(OH)_3$ and HCl. K. observed that silk or wood fibers also change blue litmus paper to red, and concludes that these fibers must act in a similar manner as the clay.

S. T. (*C. A.*)

48. A rapid method for the estimation of MgO in portland cements. MAX ALBERT. *The Chemist-Analyst*, **32**, 7 (1921).—The following modification of the standard method is simple, rapid and sufficiently accurate for cement mill and commercial laboratories. The saving in time is effected in two stages of the analysis: 1. By weighing out the samples directly into 400 cc. Pyrex beakers, instead of casseroles, and filtering off the silica together with the iron and alumina. The phys. and chem. properties of Pyrex glassware are such, that they safely permit the baking of the dry residue from the evap. of the initial HCl solution of cement. Also, a separate filtration of the silica is avoided. 2. By volumetric determination after precipitation of magnesium ammonium phosphate. For this purpose the magnesium ammonium phosphate precipitate after filtering and washing (three times with 5% ammonia and twice with 95% alc.) is transferred to a 100 cc. beaker and allowed to dry. Then add 10 cc. stand. 0.1 N H_2SO_4 and three drops of methyl orange. When solution is complete add 15 cc. hot water and titrate excess H_2SO_4 with standard 0.05 Na_2CO_3. Compute MgO. By means of this method 6 determina-

tions can be made in $5^1/_2$ hours as against 9 hours required by the stand.. method. Check determinations indicate a max. error of 0.05% in MgO. Method is also applicable to *clays* and *limestone*. (*C. A.*)

49. The physics and chemistry of colloids and their bearing on industrial questions. Some observations on peptization and precipitation. N. G. Chatterji and N. R. Dhar. *Chem. News*, **121**, 253–6 (1920).—AgCl, Ag_2CrO_4, and calcium silicate are not peptized in the presence of concd. soln. of cane sugar (contrary to Bancroft—2nd Annual of Brit. Assn. on Colloid Chem.). Hydroxides of Fe, Ni, Th, Hg, Co, etc., were peptized by adding NaOH to solns. of the respective salts in presence of glycerol or sugar (in the case of V and Au, NH_4OH should replace NaOH). But glycerol and sugar will not peptize the hydroxides if added subsequent to pptn. It is a curious fact that prompt pptn. occurs if the salt soln. be added to a mixture of glycerol and the alkali hydroxide. No peptization seems to occur with $Sb(OH)_3$, CuF_2, or $BaSO_4$. The cond. of a soln. of NaOH is not appreciably changed by the addition of the hydroxides of Cr, Al, Pb, Hg, but in the case of Zn the resistance increased appreciably. "Hence we can conclude that the solns. of $Al(OH)_3$, $Cr(OH)_2$, $Pb(OH)_2$, $Hg(OH)_2$, and $Cu(OH)_2$ are cases of true peptization and not of chem. combination. On the other hand, in the case of $Zn(OH)_2$, we get more of the chem. combination than of peptization." Confirming the work of Bentley and Rose (*C. A.*, **7**, 3882) freshly pptd. $Al(OH)_3$ is peptized by acetic acid; so also are $Fe(OH)_3$ and $Cr(OH)_2$. But with $Zn(OH)_2$ the cond. rises greatly, indicating that this more strongly basic hydroxide has mainly formed Zn acetate. Blue $Cu(OH)_2$ containing a trace of undecomposed Cu salt is stabilized by it, and does not turn black on boiling as would otherwise be the case. The protective adsorbed Cu salt may be washed out by *hot* water, and the black $Cu(OH)_2$ may be rendered blue on boiling with a trace of Cu salt. In general the stronger the kind of alkali, the more rapid was the change from blue to black—KOH > NaOH > $Ba(OH)_2$, etc. The color change of $Co(OH)_2$ from blue to pink is analogous to that of $Cu(OH)_2$ and is similarly effected by catalysts. "All those salts which produce a hydroxide sol. in excess of NaOH, namely, salts of Zn, Al, Sn, Pb, etc., markedly retard the transformation of both the blue $Cu(OH)_2$ to the black form, as well as that of the blue variety of $Co(OH)_2$ to the pink form. It seems probable that the presence of $Al(OH)_3$, $Pb(OH)_2$, $Sn(OH)_2$, etc., in the colloidal state tends to peptize the $Co(OH)_2$ or the $Cu(OH)_2$." $Fe(OH)_2$ when pptd. in solns. of the hydroxides of Al, Cr and Zn in NaOH, adsorbs and carries down some of the latter hydroxides. Jerome Alexander. (*C. A.*)

50. A graphical method for the interpretation of flue gas analysis. Gilbert B. Howarth. Univ. Leeds. *J. Soc. Chem. Ind.*, **39**, 329–33T (1920).—Lengthy calcns. are generalized by coördinate charts to show (1) the ratio of the amt. of air supplied for combustion to the minimum theoretical amt. for complete combustion; and (2) the ratio of the amt. of heat in the hot flue gases to that liberated by combustion of the fuel. Four variables are involved, of which it is necessary to know two: (1) The % extra air based on the

minimum required for combustion; (2) the % O in the dry flue gases; (3) the % CO_2 in the same; (4) a const. depending on the compn. of the fuel. These 4 variables are plotted so that if the values of any 2 are known, the others are detd. The method is most useful when the constant (fuel factor) is known, so that detn. of the % CO_2 alone in the dry flue gases gives the % O and the extra air. These graphs are applicable to nearly all fuels. The value of the fuel factor from lignite to anthracite varies from 0.63 to 0.40, representing a difference of 0.5% in CO_2. The detn. of any physical property of the flue gases may be made by superimposing curves on the extra-air diagram. In this way measurements can be made on flue gases satd. with H_2O at any temp. by a series of curves. Also in *Blast Furnace & Steel Plant*, 9, 175–8 (1921). C. C. DAVIS. (*C. A.*)

51. Heat of sublimation of carbon. H. KOHN. Univ. Breslau. *Z. Physik*, **3**, 143–56 (1920).—K. shows that Fajan's calcn. of the heat of sublimation, λ, of C (*C. A.*, **14**, 1623) from the pressure-intensity relation of the C arc can be improved in the matter of temp. measurement. With the temp. correction the value of λ for C is 163.5 kg.cal. (168 for diamond).

F. C. HOYT. (*C. A.*)

52. Identification of quartz particles in konimeter samples. A. W. ROGERS. *J. Chem. Met. Soc. S. Africa*, **21**, 11 (1920); cf. *C. A.*, **14**, 2455.—Further expts. showed that while *o*-toluidine of n 1.57 worked well on dry quartz and mica dust, it was a failure on konimeter samples, as it did not dissolve the vaseline sufficiently. Dimethylaniline dissolved the vaseline, but rendered the quartz particles almost invisible, the dissolved vaseline lowering the n to the same av. as that of quartz. $CHBr_3$ and C_6H_5Br were tried. The liquid finally recommended was a mixt. of 5 pts. C_6H_5Br and 1 pt. α-bromonaphthalene, which is permanent, gives no crystals on keeping, practically nonvolatile and dissolves vaseline. Four parts of this mixt. plus 1 of vaseline of n 1.492 gave a mixt. having the required n, 1.57. L. W. RIGGS. (*C. A.*)

53. Adsorption by silica gel. E. B. MILLER. *Chem,. Met. Eng.* **23**, 1155–60, 1219–22, 1251–4 (1920).—In this series of papers are considered the basic facts and observations on adsorption of vapors by silica gel. G. L. C. (*C. A.*)

54. The viscosity-concentration function of polydispersed systems. H. LÜERS AND M. SCHNEIDER. Munich. *Kolloid-Z.*, **27**, 273–7 (1920).—The relation of viscosity to the concn. of polydispersed systems of flour and water (rye, wheat, malt and barley flour) is expressed by $\eta_s = \eta_0 (1 + kf + k_1 f^n)$ in which η_s = the viscosity of the suspension, η_0 = that of water (1), f = the ratio of the vol. of the dispersed phase to the total volume, k, k_1 and n are consts. This is similar to the equation of Ostwald and Mundler for the osmotic pressure of dispersoids (*C. A.*, **13**, 1412). The theoretical equation of Hess (*C. A.*, **14**, 3176) $\eta_s = \eta/(1 - \alpha k)$ in which k is the vol. of the dispersed phase in unit vol. of the system and α a function of the vol. due to the "dead space' about each particle, fits the observed viscosities about equally well.

H. I. MATTILL. (*C. A.*)

55. Colloid development. Harry N. Holmes. *J. Ind. Eng. Chem.*, **13**, 357 (1921).—Contains selected bibliography of 25 titles.

56. Humidity control by means of sulphuric acid solutions, with critical compilation of vapor pressure data. Robt. E. Wilson. Mass. Inst. Tech. *J. Ind. Eng. Chem.*, **13**, 326 (1921).

57. The structure of precipitates. Sven Odin. *Svensk Kem. Tidskrift*, **32**, 74–85, 90–98, 108–110 (1920).—An important contribution to the laws governing the nature of the particles obtained by the settling of suspended material such as kaolin. The character of the prec. and the influence of electrolytes are discussed in detail. For extended abstract see *C. A.*, **15**, 971 (1921). Esc.

58. The angle of slope (Böschungswinkel)—a new physical constant. A. Langhans. *Kolloid-Z.*, **27**, 101–23 (1920).—This const. is defined as the angle (β) which the sloping side of a pile of discrete material forms with the horizontal. The original must be consulted for complete data on the 90 different salts, metallic powders, and org. compds. studied by L. Extensive tables give the value of β detd. by 3 methods in each case together with measurements of the av. size of the particles and their sp. wt. Values found in the literature for *sand, clay, gravel*, etc., are also tabulated, and the importance of this const. in relation to the handling of such substances is emphasized. App. and methods for the accurate detn. of β are given. L. discusses the theory involved, and the relationship of β to the sp. wt., size, and coeff. of friction of the particles. H. W. Banks, 3rd. (*C. A.*)

59. Mica in Australia. B. Dunstan. *Min. Mag.*, **24**, 120.—In the *Queensland Gov. Mining J.*, for Oct., 1920, D. gives an account of the mica production of the world. There are a number of mines in Australia, none of which are being worked at the present time. Probably the most important of these is the Rifle Creek area near Cloncurry, Queensland. Here there are a number of mica-bearing pegmatite dikes. One dike examined was 10 to 12 ft. wide and made up almost entirely of crystals of mica. The weathered material (which is all that has been sampled as yet) has tested quite satisfactorily in spite of its condition. Another important deposit of similar nature is at Hart's Range near the Arltunga goldfield in the Northern Territory. From present imperfect knowledge the fields appear to be quite promising but development is held back by the lack of transportation and other facilities.

60. Bauxite-aluminum ores in West Australia. Anon. *Min. Mag.*, **23**, 352–3 (1920).—The purpose of the article is to furnish a brief description of W. Australian bauxite deposits for the use of investigators. It consists of a description of the lateritic bauxite deposit of the Darling Range together with suggestions for the examination and the estimation of the aluminum content in the field.

61. Mineral production of Canada for 1919. Canada Dept. of Mines, Mines Branch. Gives statistical data on the Canadian production of *Abrasive*

Materials, Barite, Feldspar, Quartz, Talc, Cement, Clays, Graphite, Magnesite, and *Mica.*

62. **Clay.** Report of the Colorado Coal Fields of Texas. N. F. DRAKE. University of Texas, *Bull.* **1755**, 69–70, Oct., 1917.—The clays of this district fall into two classes, (1) those which occur in the regular beds interstratified with other rocks and (2), alluvial material derived by erosion from clays of the first type, and deposited in the valleys. The alluvial type contains considerable sand and is used for common brick. Sample analyses show that iron and other fluxing elements are high in all the clays. D. D. SMYTHE.

63. **The talc industry in 1920.** RAYMOND B. LADOO. Bur. Mines, *Repts. of Investigations,* No. **2204,** 5 pp. (1921). E. H. (*C. A.*)

64. **Asbestos.** OLIVER BOWLES. *Eng. Mining J.,* **111,** 155 (1921). **Barytes.** J. B. PIERCE, JR. *Ibid.,* 155. **Fuller's earth in Georgia.** S. W. McCALLIE. *Ibid.,* 156–7. **Graphite industry.** BEN. L. MILLER. *Ibid.,* 157. **Gypsum.** FRANK A. WILDER. *Ibid.,* 157. **Magnesite.** R. W. STONE. *Ibid.,* 158. **The mica industry.** J. VOLNEY LEWIS. *Ibid.,* 158. **Monazite.** H. C. MEYER. *Ibid.,* 158. **Potash.** F. W. BROWN. *Ibid.,* 159. **Strontium.** J. B. PIERCE, JR. *Ibid.,* 160. **Talc and soapstone.** RAYMOND B. LADOO. *Ibid.,* **161.**—Reviews from the point of view of mining and industry. E. J. C. (*C. A.*)

65. **Cristobalite in the spherulitic obsidian from Yellowstone National Park.** AUSTIN F. ROGERS. Stanford Univ. *Am. Mineral.,* **6,** 4–6 (1921).—The n of the obsidian is 1.480, which proves that it is rhyolitic, and high in SiO_2. In the lithophysae are rods of orthoclase, with $n = 1.523$, and cristobalite, in minute spherical aggregates. It is readily identified by its n, 1.485, and by its behavior on heating and then cooling, when it becomes opaque suddenly at a transition point around 200°. E. T. W. (*C. A.*)

66. **Economic minerals of Madagascar.** GEORGE F. KUNZ. *Eng. Mining J.,* **111,** 14–6 (1921).—An article compiled from an address by A. Larcoix at the French Natl. Museum of Nat. History, Paris, May 2, 1920, and an article by Duparc on minerals of the pegmatites, published in Geneva in 1910. Notes are given on *graphite, corundum* and *rare earths.* E. V. SHANNON. (*C. A.*)

67. **Can Swedish quartz be substituted by German sandstone?** P. BARTEL. *Keram. Rundschau,* **28,** 449–50, 459–60 (1920).—Müller (*Keram. Rundschau,* **1903,** 652) found that it was possible to produce fine translucent porcelain by using pure sand. He further states that the sand should not be used in the moist condition but should be calcined before using. Grimm (*Sprechsaal,* **1905,** 925) found that if sand was calcined and ground to the same degree of fineness as quartz it produced products equally as good as those obtained by using quartz. Calcined quartz can be ground to the proper degree of fineness in 18–24 hrs. and calcined sand in 20–28 hrs. Pure sand is used for making high grade glass and glazes. Reike and Endell (*Silikat-Zeit.,* **1913,** 48) found

that bodies containing sand were grayer than those containing quartz even when the sand was purer than the quartz. This is attributed to a difference in the structure of the sand and quartz grains in bodies. The sand grains do not become cracked or shattered upon heating as the quartz grains do and hence sand grains do not reflect the light from as many surfaces. Quartz is used by B. for making the finer porcelains, but sand is used for making the coarser ware. In attempting to use sand for the finer ware it was found that it produced a body which was not as translucent as quartz bodies and it was open, due to the coarser grains of sand. H. G. SCHURECHT.

PATENTS

68. Ultramarine. J. B. GIUMET and A. GUILLOCHIN. Brit., 152,916, Feb. 14, 1920.—Sulfites or bisulfites of the alkalies, or mixts. of these salts are used in the manuf. of blue and green ultramarines to replace wholly or partially the alkali carbonates or sulfates usually employed. The Na_2SO_3 obtained as a by-product in the prepn. of phenol is particularly suitable for this purpose. In an example, the furnace charge consists of *kaolin*, Na_2SO_3, S, and a reducing agent such as resin. (*C. A.*)

Abrasives

69. Abrasives. J. V. LEWIS. *Eng. Min. Jour.*, **111**, 154.—A short résumé of the abrasive industry, mainly emery and corundum, in 1920.

D. D. SMYTHE.

70. Abrasives and grinding wheels bonded with ceramic materials. KARL HECHT. *Keram. Rundschau*, **28**, 511–12, 521 (1920).—Abrasives arranged in order of their hardness are as follows: (1) carborundum with 70% SiO_2 and 30% C (2) artificial corundum with 96% Al_2O_3, (3) emery with 60–70% Al_2O_3, and (4) emery with 48–69% Al_2O_3. Carborundum is best suited for metals which are easily torn (as brass), and corundum is best suited for cast steel, cast iron and hard and soft steel. A mixt. of clay and a feldspar frit is used as a bond. The bond should be soft for grinding hard steel but should be hard for grinding cast iron since it is desirable to have the abrasive particles remain intact until they are worn smooth. According to a patented process the Schliefmachinen and Scliefrader-Werk, Friedrich Schmaltz, G. m. b. H., separate the abrasive material from old grinding wheels by grinding, heating under pressure with an alkaline solution which causes the bond to swell, and finally removing the bond by treatment with dilute acids. H. G. S.

PATENTS

71. Abrasive compositions. F. P. JONES and A. FLEMING. Brit., 153,692, Aug. 18, 1919.—A substitute for pumice blocks, etc., for abrasive purposes consists of SiO_2, sand, firestone, glass, china or the like 76 parts by wt., MgO 7, $MgCl_2$ 7, wax, sawdust, S, or NH_4Cl 10, and H_2O 10 parts. The compn. is molded, and after setting is heated to melt the wax, S, etc., or to char the sawdust. According to the provisional specification, pores may also be pro-

duced by the addition of a sol. salt, which is washed out after the compn. has set. The compn. in that case may be SiO_2, sand, etc., 75 parts by wt., port. cement 15 parts, NaCl 10–20 parts and sufficient H_2O to bind. (*C. A.*)

See also Abst., No. 44.

White Ware and Porcelain

72. **A colorimeter operating on the subtractive principle.** L. A. JONES. *J. Optical Soc. Am.*, **4**, 420–30(1920).—For field and com. use, a colorimeter utilizing the subtractive principle of color mixt. seems to combine best the features of portability, simplicity of operation and freedom from the necessity of delicate adjustment of parts. An image of the object whose color is to be measured is brought by a lens system so that it occupies one-half of the field of the colorimeter tube. A neutral gray filter can be used if necessary to control the intensity of the light from the object so that it shall fall within the range of the instrument. The standard of comparison is an incandescent bulb which, with the proper current supplied through a control box and a suitable filter, gives a light matching noon sunlight; this is checked occasionally against a standard light. Four gelatin wedges are so placed that they may be inserted to any extent or withdrawn completely from the path of the beam of light from this source to the fields of the instrument. Three of the wedges are of the subtractive complementary colors: minus green (transmitting red and blue), minus blue (transmitting red and green), and minus red (transmitting green and blue); the fourth wedge is neutral gray to control the light intensity. By proper adjustment of these wedges any color can be matched; the position of each wedge is indicated by a pointer and can be read on a graduated scale. While the instrument was designed primarily for the measurement of the color of objects at some distance, it can be easily adapted to examine transparent colored solids, liquids, or reflecting surfaces.

D. W. M. (*C. A.*)

73. **The manufacture of pressed porcelain.** ERICH RUTH. *Keram. Rundschau*, **29**, 33–9 (1921).—Porcelain electric insulators are either turned or pressed. The high tens. insulators are usually turned. For pressed insulators cheaper materials may be used. The bodies after being dried are mixed with *pressing oil* and water and after storing are pressed. Many pieces may be made by automatic machinery.

74. **The mechanical properties of porcelain.** E. ROSENTHAL. *Keram. Rundschau*, **29**, 81–2, 93–4 (1921).—The strength of porcelains may be divided into two classes (1) resist. to static pressure, *i. e.*, when the load is applied slowly and (2) resist. to impact, *i. e.*, when the pressure is applied suddenly. The compression and tens. strengths are determined in the customary manner. The torsion strength which heretofore has never been determined is about 430 kgs./cm.^{2} while that of cast iron is 2228 kgs./cm.^{2}, and for cement is 35.7 kg./cm.^{2} The vol. of transmission or vibration of sound varies with the mod. of elast. Those having the highest velocity are the best porcelains.

This vel. may be increased by increasing the clay content. Also pure light burning clays give better results than impure clays. The impact tests are made by the Marten method by letting a pendulum drop on to the test piece from different heights until breakage occurs. The results of this test checked closely for different sizes of test pieces. The following results were obtained on a number of porcelains:

	A	B	C	D	E	F	G	H
1—Insulator body G	4000–	...	481	590	0.90	98	...	2.4
2—Insulator body H	5000	261	500	540	0.95	105	5630	3.3
3—Table ware	...	...	...	640	1.36	112	...	...
4—Chemical porcelain	...	...	500	410	1.23	117	5930	...
5—Hermsdorfer hard porcelain	4780	...	...	490	...	...	5050	...
6—Hard porcelain No. 6292 (Amer.)	...	...	...	520	0.08	...	...	...
7—Seger porcelain, No. 6833	...	...	430	...	1.00	69	5340	...
8—Special body No. 6412	...	...	...	980	2.40	146	...	1.7
9—Special body No. 6048	...	...	...	...	1.61		6680	...
10—Glasspot body	...	...	...	...	0.34	8	...	...
11—Refract. body	...	...	...	...	0.33	7	...	...

A = Compress. strength kg./cm.^{2} (B) Tens. strength kgs./cm.^{2} (C) Torsion strength, kg./cm.^{2}. (D) Cross-breaking strength, kg./cm.^{2} (E) Impact cross-breaking strength, cm., kg./cm.^{2}. (F) Impact compress. strength, cm., kg./cm.^{2} (G) Vel. of transmission, m./sec., and (H) Loss in volume from sand blasting. *One test is not sufficient to measure the strength of porcelains.* Many porcelains which stand up well in one test fail in another. This is true of the Amer. porcelain 6292 which stands up well in cross-breaking strength but fails in the impact test. Bodies G and H also stand up well in cross-breaking strength but fail to show a high resist. to impact.

H. G. Schurecht.

75. **Tennessee ball clay and its manufacturing possibilities.** W. A. Nelson. *Mfgr's. Record*, Baltimore, Md., Feb. 17, **1921**, 6 pp.—Although Tenn. produces ball clay equal to the famous Eng. ball clays, and lies in a region of cheap fuel the South is still supplied with tableware made in northern plants from Tenn. clays. Other raw materials can be obtained from neighboring states at rates equal to or less than those which the northern concerns must pay, while the labor cost, the most important single factor in the cost of pottery production, is fixed regardless of location. It would appear therefore that southwestern Tennessee would be an excellent location for plants which would supply the south with tableware, since freight rates, a very considerable item on chinaware, would be most advantageous from this location. The most important clay deposits, all of which occur in Henry and Carroll Counties, are described in this article. A list of the leading clay producers of Tennessee is given together with maps showing the location of their pits. The uses of ball clay are mentioned and a few figures given regarding the production and prices.

D. D. Smythe.

Glass

76. **A new method of joining glass.** C. O. Fairchild. *J. Optical Soc. Am.*, **4**, 496–503 (1920); cf. Parker & Dalladay. *Trans. Faraday Soc.*, **12**, 305.—This method is particularly applicable for joining lenses, making colorimeter tubes, plane glass incandescent bulbs, etc. The object is heated in a small electric furnace to approx. its annealing temp., sufficiently high to avoid cracking while applying heat locally, and the junction of the two parts is rapidly passed over with a small oxy-gas blowpipe flame. By this method complete fusion of the junction can be accomplished without propagating beyond a restricted portion near the joint the stresses occasioned by local heating; hence it is applicable where a slight deformation at the junction does not impair the usefulness of the object. The furnace can be quickly heated so that a small glass article can be raised to temps. above the annealing temp., the junction completed by application of the flame, and cooling initiated before the glass has had sufficient time to appreciably change its shape. The two parts need not be of the same glass, nor need there be a perfect fit; the method fails only for glasses which have too widely differing coefficients of thermal expansion. Donald W. MacArdle. (*C. A.*)

77. **Shock-defying glass.** Anon. *Mining and Metallurgy*, No. **169**, 50 pp. (1921).—Laminated glass is made in various thicknesses to withstand almost any impact to which glass might be subjected. Glass for bank tellers, cages is made of three thicknesses of glass. The middle section is plate glass nearly $^9/_{16}$ in. thick; the two outer parts are $^1/_8$ in. thick. Between the core and the outer sheets are imposed sheets of transparent pyroxylin 0.2 in. thick. A piece of glass of this compn., 6 in. square, was shot at from a distance of 3 ft., with a rifle using a 32-caliber, nickel-jacketed, flat nose, high-velocity rifle bullet. The bullet powdered the glass at the point of impact over an area $1^1/_2$ in. in diam. The bullet, however, penetrated only the top layer of the glass and the sheeting was exposed only in one spot about $^3/_8$ in. in. diam., but it was not even dented by the bullet. The heavy plate-glass core was broken as was the under-sheet of glass, but was not penetrated and the only glass that fell from the underside of the block were some pieces so small that they could have caused no injury had they fallen on a person even from a great height. Glass for windows liable to be subjected to shock from explosions need only be the thickness of two ordinary sheets of window glass with one sheet of pyroxylin sheeting between them. The lamination is effected by hydraulic pressure. If an explosion causes the glass to crack, it is prevented from falling by the pyroxylin core. Charles E. Munroe. (*C. A.*)

78. **British chemical glass industry.** S. N. Jenkinson. *Chem. Age* (London), **3**, 619 (1920).—The leading British chem. glasses are compared with Jena glass, for resistance to action of boiling HCl and HCl vapor. For figures see *C. A.*, **12**, 212. (*C. A.*)

79. **Normal or standardized fittings.** Alfred Stock. *Z. angew. Chem.*, **33**, I, 280 (1920).—Could one replace the varied cuts or tapers on stopcocks,

necks of vessels, etc., with normal or standard forms, making the parts interchangeable, it would mark an extraordinary advance in app. manuf. To be entirely successful such parts must be made so as to require no final grinding or fitting by the purchaser and user. Adapters and connections for extn. flasks and other app. are better when made of the insert, rather than the slip-over or cap type. W. C. Ebaugh. (*C. A.*)

80. Two laboratory applications of the triode valve. J. Scott Taggart. *Electrician*, **86**, 124 (1921).—The app. described distinguishes between infinite resistance and one of very high value. It was used to determine the temp. at which *glass* begins to conduct electricity. Ed.

81. The effect of temperature upon the infra-red absorption of certain glasses. G. E. Grantham. *Phys. Rev.*, **16**, 565–74 (1920).—An investigation to study the effect of temp. upon the infra-red absorption spectra of the same specimens used by Gibson (*C. A.*, **10**, 1001) and to see whether the shift of the edge of an absorption band was coincident with a shift of a transmission band lying largely in the infra-red or resulted in a narrowing of such a transmission band. In addition, measurements were made on a specimen of Corning G. 585 blue glass of 1.98 mm. thickness. The 5 specimens were in turn placed in a furnace and the absorption spectra studied between 0.6 and 4.0 μ for temps. of 80°, 307° and 440°. The core of the furnace was an Fe cylinder, 12 cm. long and 8 cm. diam., through the axis of which a hole 2.5 cm. in diam. was bored. The specimen was cemented to an Fe slide which fitted snugly into a slotted sleeve located at the middle point of the Fe core. The heating element was a coil of Fe wire wound around the cylinder over asbestos paper soaked in water-glass. The source of radiation was a 400-w. N-filled W lamp, which was placed against the end of the furnace and under conditions of thermal equil. gave a temp. of 80° at the specimen, with no current in the heating coil. A Hilger infra-red const. deviation spectrometer equipped with a Coblentz Bi-Ag thermopile was used. Temps. were measured by a Cu-constantan thermocouple, the junction of which was in contact with the specimen. A Coblentz astatic galvanometer was used, the sensibility obtained being about 3.3×10^{-11} amp. per mm. at 3 m. distance. For measurements between 2.0 and 4.0 μ, the correction due to the radiation from the furnace and specimen had to be detd. The red glass (Zn, colored with Cd-Se) showed a decrease in absorption with temp. rise over the whole range except for wave lengths less than 0.75 μ, when the absorption increases with temp. rise. There is evidence of a shift of the whole transmission band toward the less refrangible portion of the spectrum. For the orange-colored glass (non-Pb, colored with Cd-Se), there is indication of a slight shift with temp. rise of the transmission band extending over about the same region, 0.7 to 2.7 μ, as the transmission band of the red glass. There is a very slight increase in transmission throughout this band. At the 3.3 μ absorption band there is a marked increase in transmittance with temp. rise. The yellow-amber glass (borosilicate, colored with Cd-Se) showed a shift of the whole transmission

band toward the longer wave lengths with temp. rise and slight decrease in transmittance except in the region of absorption bands, when the transmittance increases. The lemon-yellow glass (Zn, colored with Cd-Se) shows at high temps. a decrease of transmittance throughout the range from about 0.6 to 2.4 μ. In the case of the blue glass, having sharp absorption bands, a temp. increase produces a decrease in absorption in the region of absorption bands in the infra-red. The peaks of the transmission bands are shifted toward the longer wave lengths at higher temps. This is caused by an increased absorption on the long wave length side of an absorption band and a decreased absorption on the short side. Consequently the absorption band is broadened without any apparent shift in the peak. This applies particularly well to the band having a max. between 1.3 and 1.8 μ. Ascending and descending temps. give the same results in all cases. In general, temp. rise decreases slightly the absorption in the region of an absorption band and causes a shift of the transmission bands toward the longer wave lengths, the shift being greater on the more refrangible edge. A. L. FEILD. (*C. A.*)

82. **Electric heating in ceramics.** WIRT S. SCOTT. *Chem. Met. Eng.*, **24**, 400 (1921).—Many installations have been made for the treating of glassware. A 72-kw. furnace is used for annealing at 1200° F. This furnace is 22 in. wide, 10 ft. long and 5 ft. high and is of the overhead conveyor type. In one test several thousand goblets were annealed, the goblets being placed in metal containers consisting of nine trays each, each tray holding twenty-five goblets. Practically all the goblets proved to be A-1 grade after annealing. The natural-gas-fired furnaces in the same factory gave very few A-1 grade goblets, the majority being B-1 grade, with a quantity of C-1 grade. All glasses passed through the electric furnace were bright polish finish. In using an electric furnace for fusing bifocal lenses the loss was 3 to 4% compared to 20% with natural gas furnaces. Electric furnaces are being used successfully also for firing enameled steel articles. H. F. S.

83. **Composition of glass for lamp chimneys.** *Schnurpfeil's Review for Glass Works*, **4**, No. 48, 797 (1921).—Two batches gives (1) sand, 1000 lbs.; soda ash, 700 lbs.; limestone, 290 lbs.; antimony, 1 lb.; arsenic, $1^1/_2$ lbs.; nickel oxide, $^1/_2$ oz. (2) Sand, 1000 lbs.; soda ash, 700 lbs.; limestone, 280 lbs.; lead, 20 lbs.; arsenic, 1 lb.; manganese, $1^1/_4$ lbs.; saltpetre, 2 lbs.; nickel oxide, $^1/_4$ oz.

84. **Composition of glass for pressed tumblers.** *Schnurpfeil's Review for Glass Works*, **4**, No. 48, 797 (1921).—Sand, 100 lbs.; soda ash 34 lbs.; lime, 12; barytes, 10; saltpetre, 1 lb.; arsenic, $^1/_2$ lb.; manganese, 5 oz.

85. **Composition of glass for electric lamp bulbs.** *Schurpfeil's Review for Glass Works*, **4**, No. 48, 797 (1921).—Sand, 100; soda ash 30; red lead, 35; lime, 5; saltpetre, 4; borax, 2; manganese, $^1/_4$; arsenic, $^1/_4$. R. J. M.

86. **The phenomena of rupture and flow in solids.** A. A. GRIFFITH. Roy. Aircraft Establishment. *Phil. Trans. Roy. Soc. Lon. A*, **221**, 163–98

(1920).—The theory of the subject is rather fully discussed and numerous expts. made with a hard Eng. *glass* of the following per cent comp. and properties: SiO_2 69.2; K_2O, 12.0; Na_2O, 0.9; Al_2O_3, 11.8; CaO, 4.5; MnO, 0.9; sp. gr., 2.40; Young's mod., 9.01 × 10 lbs. per sq. in. Poisson's ratio 0.251; tens. strength, 24,900 lbs. per sq. in. *Surface tension:* At 1100°C. the s. t. was meas. by Quincke's drop method (no details given). Between 900° and 730° C it was meas. by obs. the angle of sag, of a horizontal fibre weighted in the middle. Fibres 2 in. long and 0.002–0.01 in. diam. (d) were used the s. t. (T) being calc. from the relation d. T. sin $^1/_2$ = w, where w is the susp. wt. The following results were obtained showing that the s. t. of glass is approx. a linear function of the temp.

t°C	1110	905	896	852	823	820	801	760	744	15
T.10³ lbs. per sq. in....	2.30	2.39	2.50	2.49	2.54	2.49	2.57	2.55	2.51	Extrap. 3.1

Below 730° the glass did not behave as a viscous liquid but rather as a plastic solid its yield value in lbs. per sq. in. being 0 at 730°, 1.3 at 657°, 24 at 540° and increasing very rapidly at lower temps. *Bursting strength of cracked bulbs and tubes:* "The breaking load of a thin glass plate having a sufficiently long straight crack normal to the appl. stress, is invers. prop. to the sq. rt. of length of the crack. *Strength of thin fibres:* To secure uniform results the glass must be heated to 1400–1500°C before drawing, the temp. during drawing should not fall below 730°, and the fibre should be allowed to age several days before testing. With this procedure the following results were obtained.

Tensile Strength of Glass Fibers

Diameter 0.001 inch	Breaking Stress lbs. per sq. inch	Diameter 0.001 inch	Breaking Stress lbs. per sq. inch
40.00	24,900	0.95	117,000
4.20	42,300	0.75	134,000
2.78	50,800	0.70	164,000
2.25	64,100	0.60	185,000
2.00	79,600	0.56	154,000
1.85	88,500	0.50	195,000
1.75	82,600	0.38	232,000
1.40	85,200	0.26	332,000
1.32	99,500	0.165	498,000
1.15	88,700	0.130	491,000

The paper concludes with a discussion of the *mol. orientation theory*, the *practical limitations of the theory of elasticity*, methods of *increasing the strength of materials*, and applications to the theory of liquids. Ed.

87. Some common defects occurring in glass. J. B. Krak. *Glass Ind.*, **2,** 1–3 (1921).—*Causes and prevention or elimination of seeds and stones.* Seed may be caused by too much CO_2 or CO in the flame above the glass, and also by too high a temp. or too much alkali; it may be avoided by regulation

of the stack draft, by temp. control and by proper compounding of the batch. Sometimes the evolution of gas from an onion or potato is effective, or arsenic may be used. Batch stones, pot stones and cap stones are briefly discussed.

88. Progress made in plate glass manufacture. J. W. CRUIKSHANK. *Glass Ind.*, **2**, 3–6 (1921).—The method of teeming plate glass twenty years ago is described and compared with the present day mechanical method in which machines have largely taken the place of men. While there have been no fundamental changes of process, great progress has been made toward perfecting the art.

89. Manufacture of mother-of-pearl glass. O. SCHWARZBACH. *Sprechsaal*, **53**, 251 (1920).—Translation by H. W. Craver in *Glass Ind.*, **2**, 7–8 (1921). Cf. *Cer. Abstracts*, **3**, 928.

90. Glass industry in England and the United States. W. E. S. TURNER. *Glass Ind.*, **2**, 10–11 (1921); also *Pottery and Glass Record*, Dec. 15, 1920; cf. *Cer. Abs.*, **3**, 421.

91. Cutting bottle molds automatically. *Glass Ind.*, **2**, 23 (1921).—Description with illustrations of machine developed by the Keller Mechanical Engraving Co., for cutting two duplicates of any bottle mold half, simultaneously.

92. Recent simplex lehr installation. *Glass Ind.*, **2**, 24 (1921).—Description of installation at the plant of the Federal Glass Co., Columbus, Ohio.

93. Devitrification and revitrification of glass. J. B. KRAK. *Glass Ind.*, **2**, 29–31 (1921).—A brief discussion of the nature of these changes and the circumstances under which they occur.

94. Glass melting in shallow pots. *Sprechsaal*, **53**, 205 (1920).—Translated by H. W. CRAVER in *Glass Ind.*, **2**, 32–4 (1921); cf. *Cer. Abstracts*, **3**, 929.

95. Evolution of the mold industry. GEORGE B. ARDUSER. *Glass Ind.*, **2**, 35–6 (1921).—A brief statement chiefly relating to present practice.

96. Saving fuel by controlling chimney losses. F. F. UEHLING. *Glass Ind.*, **2**, 37–9 (1921).—*In the average boiler plant*, 35 per cent of the heat generated is lost in gases going up the stack, while only 4 per cent is lost by radiation and only 4 per cent is lost in unburned coal. The excessive loss up the stack is usually due to lack of instruments for determining whether the proper amount of air is being supplied. The percentage of CO_2 is the most important index. CO_2 recorders should be in every plant, and fireman should be instructed to keep the CO_2 content close to the maximum safe percentage.

97. Automatic bottle manufacture. GEORGE E. HOWARD. *Glass Ind.*, **2**, 55–9 (1921).—A discussion and comparison of the Owens process and the more recent feeder processes of bottle manufacture, by the inventor of the Howard feeder.

98. Bloomery furnaces and other turned pieces made on a potters wheel. A. H. WESSELY. *Sprechsaal*, **54**, 1–2 (1921).—A brief description of an old art.

99. Fuel and heat used in glass works. H. MAURACH. *Sprechsaal*, **54**, 36–8 (1921).—The quantities of coal used per annum by the *German glass industry* from 1913 to 1920 are given and also a comparison of the coal used per annum by the lime, glass and porcelain industries before and after the war. The importance of conserving fuel is emphasized and in that connection data are given as to the *thermal efficiency of typical glass furnaces*. Of the heat obtained from the coal, 15 per cent is lost in the producer, 19 per cent goes up the stack, 43 per cent is lost by radiation and conduction from the furnace itself and 10 per cent from the conduit pipes and regenerators, and only 12.5 per cent goes into the glass. It is stated that in practice from 1 to 1.3 lbs. of coal are required to produce 1 lb. of glass. C. G. W.

PATENTS

100. Glass; artificial stone. P. B. CROSSLEY. Brit. 152,780, July 22, 1919. Non-fragile glass, which can be rolled, forged, extruded, cast, etc., is made by dissolving in the dry state such silicates as micaceous or asbestos minerals in molten glass or similar silicate. The glass, etc., is chosen so as to melt at a temp. below the temp. at which the mica, etc., effloresce. If the product is to be machined, an excess of mica, etc., should be present over the amt. required to form a satd. soln. (*C. A.*)

101. Preparing glass, china and like surfaces for varnish. F. MEYER. Ger. 319,744, July 8, 1919. Addition to 317,656 (C. A. **15**, 183). The glass, china or like surface is roughed by means of H_2F_2. (*C. A.*)

102. Sheet-glass-drawing apparatus. JAMES WHITTMORE. U. S. 1,362,378, Dec. 14, 1920. A sheet glass drawing apparatus having a tank with a free lateral outlet through which the glass may flow and a travelling drawing conveyor. A cooled metal drawing lip below the level of the glass, over which the glass flowing out from the tank may be drawn.

103. Double ring for glass factories. JOSEPH DURIEUX. U. S. 1,367,027, Feb. 1, 1921. A glass drawing ring including an inner and an outer wall of semi-elliptical outline and disposed in parallel spaced relation, straight walls connecting the respective ends of the semi-elliptical walls and disposed in spaced relation, the inner wall being of greater depth than the outer wall, and spacing webs disposed between and connected to the curved or semi-elliptical walls and the straight walls. C. M. SAEGER, JR.

See also Abst. No. 72.

Enamels

104. The phosphorescent sulfides and their applications. A. A. GUNTZ, *Chimie et industrie*, **4**, 597–611 (1920).—A general review of the history of the phosphorescent sulfides, the theories advanced to explain their action, their principal properties, and the various industrial applications to which they

have been put, including those depending on the action of ultra-violet light, X-rays, Ra and other radioactive substances and light. A. P.-C. (*C. A.*)

PATENTS

105. Radium luminous coatings. E. O'HARA. U. S. 1,364,950, Jan. 11. Watch or clock dials or similar articles are enameled, luminous markings are applied over the enamel and the markings are covered with a protective coating free from Pb and vitrified on the luminous surface. U. S. 1,364,951 relates to a similar method of prepg. luminous dials in which the luminous material, *e. g.*, Zn sulfide $RaBr_2$, is mixed with a reflux or glaze which is fired or vitrified on the surface after application as a coating or marking. The glaze may be a potash lime glass. (*C. A.*)

106. Soldering enamel ware, etc. W. B. JOHNSON-LAIRD. Brit. 153,445, Oct. 10, 1919. In tinning and soldering porcelain enamel ware, the solder is applied to the glazed surface of the enamel or to both the enamel and any exposed Fe portion, by the use of a steel brush or other steel tool without the aid of a soldering-iron or flux. The surface is cleaned and brightened and the vessel then heated over a gas ring, etc. Solder is then applied by the steel tool, etc., until the surface is tinned and more solder is then applied. The solder may consist of 30% of Sn, 10% of Zn and 60% of Pb. According to the provisional specification, the solder may consist of 75% of Sn, 15% of Zn and 10% of Pb. (*C. A.*)

Brick and Tile

107. Comparative cost of steam and electric power in the brick industry. O. C. Cordes, *Clayworker*, **75**, 251–2 (1921).—

POWER COST PER 1000 BRICK

Class of Plant	Steam operated	Electrically operated	Difference	Saving % by elect. drive
Common face and tapestry brick:				
Soft mud	0.38	0.15	0.23	61
Machine made	1.23	0.96	0.27	46
Stiff mud	0.90	0.59	0.31	35
Paving brick	1.01	0.79	0.22	46
Fire brick:				
Machine made	1.23	0.97	0.27	46
Pressed brick	0.30	0.16	0.14	47

The price of coal was taken at $4.50 per ton and the price of electric power at 2.5 cents per Kw. hr.

108. The handling and shipping of brick. R. TWELLS. *Clayworker*, **75**, 226–7 (1921).—More careful handling of brick is urged. The use of gravity conveyors is recommended since they prevent the brick from being broken and permit more exact shading of the same.

109. The Chicago method of firing brick. F. H. LAMBERT. *Clayworker*, **75**, 244–8 (1921).—The method used for firing scove kilns is described. The

manner in which the hot zone travels from the bottom to the top of kiln is illustrated with diagrams.

110. Mechanical handling of brick. R. C. PENFIELD. *Clayworker,* **75,** 241–4. (1921).—A brick setting mach. picks up 750 to 1000 bricks in one operation and places them in a kiln. A similar mach. also takes 750 to 1000 bricks out of scove kilns. This system can be adapted to small plants of 50,000 brick capacity as well as at larger plants.

111. Remarks upon a new ordinance for the proper construction of chimneys. I. H. WOOLSON. *Clayworker,* **75,** 228–30 (1921).—The new ordinance advocates the lining of all flues not only to make better fire protection but also because of better draft. Losses due to defective chimneys and flues stand third on the list as productive of the greatest fire losses averaging about $14,000,000 each year.

112. Drying brick and tile. J. L. BUCKLEY. *Clayworker,* **75,** 237–8 (1921).—In the Procter system of drying, the air blows across the drier and not lengthwise as is the case with other driers. Temp., air circulation and humidity can be controlled in the system. Glass pots, high tension insulators etc., can be successfully dried in humidity driers in comparatively short time.
H. G. SCHURECHT

113. Possible uses for the spent shale from oil shale operations. KIRBY THOMAS. *Chem. Met. Eng.,* **24,** 389–90.—The spent shale might be used for *brick making* and in the manufacture of portland *cement.* H. F. S.

BOOK

114. SEARLE, ALFRED B.: **Modern Brickmaking.** 2nd Ed. revized and enlarged. New York: D. Van Nostrand Co. 510 pp. $7. (*C. A.*)

Cement, Lime and Plaster

115. Notes on the dusting of cement clinker. E. ANDERSON. *Concrete* (*Mill Section*), **18,** 140 (1921).—In the course of an investigation on the volatilization of alkalies from cement materials, the so-called dusting of the resulting clinker was frequently observed. The results indicate that although in actual mill practice, extreme cases of dusting probably occur only when the material is unduly high in SiO_2, this does not necessarily prove that the high SiO_2 content is the chief cause. It seems probable that dusting can occur as a direct result of low kiln temps. or insufficient heating.
J. C. WITT. (*C. A.*)

116. More observations on the effect of sea water on concrete. ANON. *Eng. News-Record,* **86,** 121–3 (1921).—On the Pacific Coast, from Santa Monica to Huntington, Calif., all the concrete pleasure piers with the exception of one built last summer show signs of disintegration. In general the effect is most marked between the levels of high and low tide, and along the line of reinforcement. A report is also made on the tests being carried on by the Aberthaw Construction Co. at Boston. J. C. WITT (*C. A.*)

117. Modified Vicat apparatus for study of setting time of cement. A. L. Moore. *Eng. News-Record,* **86,** 70 (1921).—The app. consists essentially of an ordinary Vicat app. in which the movable vertical rod is attached to a beam carrying a counterpoise on the other end. A reading is taken by finding the wt. necessary to cause the needle to penetrate $^3/_4$ in. into the test piece. A number of curves show the effect of various percentages of H_2O, and the results obtained by different operators. J. C. Witt (*C. A.*)

118. Cement, its inspection and testing. E. J. Mason. *Can. Eng.,* **40,** 225 (1921).—Descriptions are given of the methods in use at the Engineering Materials Laboratory, Hydro-Electric Power Commission of Ontario, reprinted from the Hydro Bulletin. J. C. Witt (*C. A.*)

119. Tentative specifications for masons' hydrated lime. Anon. *Proc. Am. Soc. Testing Materials,* **20,** Part I, 605–8 (1920).—The specifications cover chem. properties and tests, physical properties and tests, packing and marking, inspection and rejection, methods of test. E. H. (*C. A.*)

120. Tentative specifications for gypsum. Anon. *Proc. Am. Soc. Testing Materials,* **20,** Part I, 609–11 (1920).—The specifications cover forms and sizes, sampling, chem. properties, physical properties, pack and marking, inspection and rejection. E. H. (*C. A.*)

121. Tentative definitions of terms relating to the gypsum industry. Anon. *Proc. Am. Soc. Testing Materials,* **20,** Part I, 658–77 (1920). E. H. (*C. A.*)

122. Tentative specifications for calcined gypsum. Anon. *Proc. Am. Soc. Testing Materials,* **20,** Part I, 612–5 (1920).—The specifications cover classes and sizes, sampling, chem. properties, physical properties, calcined gypsum for molding or casting, packing and marking, inspection and rejection. E. H. (*C. A.*)

123. The action of chemicals on concrete. M. Jacobson and J. G. de Kèravenant. *Industrie chimique,* **7,** 391 (1920).—Brief review of the action of acids, acid salts, alkalies and alk. salts, coal-tar derivs., fertilizers, oils and fats on concrete. A. P.-C. (*C. A.*)

124. An application of the vapor pressure of potassium compounds to the study of the recovery of potash by volatilization. Daniel D. Jackson and Jerome J. Morgan. Columbia Univ. *J. Ind. Eng. Chem.,* **13,** 292 (1921).—The presence of water vapor in contact with silicate mixtures containing potassium increases the volatilization of the K during calcination, owing to the high vapor pressure of KOH. Potash is volatalized at temperatures as low as 1215°C from mixtures of feldspar with $CaCl_2$ and lime in the proportion necessary to give a *Portland Cement clinker* and also more readily from a mixture of glauconite with lime and $CaCl_2$. If the temperature is kept below the fusion point, potash can be readily volatilized from mixtures of green sand with a chloride (in the proportion to give KCl) and limestone (in proportions much lower than those used in Portland cement). In volatilizing potash as a chloride the presence of water vapor has no advantage. Ed.

BOOK

125. Howe, H. E.: **The New Stone Age.** New York: The Century Co. 289 pp. (*C. A.*)

PATENTS

126. Coating compositions; bitumen. K. Friedrich. Brit. 154,236, Mar. 27, 1918. A glaze for bricks, cement, etc., consists of cement, coloring matter, and an emulsion of a bituminous substance such as asphaltum, free from volatile oils boiling below 270°, with a soln. of an alkali such as Na_2CO_3, the emulsion being subjected to an oxidizing treatment, for instance, by adding BaO_2 before the addition of the cement. (*C. A.*)

See also Abst. Nos. 10, 48.

ACTIVITIES OF THE SOCIETY

The New Constitution and By-laws

May 2. Seventy-eight votes were cast on the question of the adoption of the new Constitution and By-Laws of the Society.

Affirmative—77
Negative —1
It is carried.

The Constitution and By-Laws as adopted will be published in the Year Book.

New Members received during April

Associate Resident

Anthony, Wm. R., Tauton, Mass., Foreman, Enameling Dept., Weir Stove Co.

Brooks, B. T., 25 West 43rd St., New York City, Chemical Engineer, Mathieson Alkali Works, Inc.

Cameron, C. V., Box V, Richmond, Cal., Supt., Pacific Sanitary Mfg. Co.

Cawood, Richard L., East Liverpool, Ohio, Vice-President and General Manager, Patterson Foundry and Machine Co.

Dunbar, George S., Columbus, Ohio, Secretary, Federal Glass Co.

Early, Joseph W., Dickson City, Pa., Supt., Early Foundry Co.

Fuller, J. R., 22 Highland Ave., Salem, Mass., Engineering Dept., Hygrade Lamp Co.

Lamborn, Lloyd, 118 East 28th St., New York City, Editor, "Chemical Age."

McMillan, H. B., Lincoln, Cal., Assistant Ceramic Chemist, Gladding, McBean & Co.

Paul, Joseph R., Newark, Cal., Enamel Foreman, Graham Mfg. Co.

Rapp, John A., 1244 Chicago Ave., Evanston, Ill.

Reedy, A. J., Battle Creek, Mich., Supt., A-B Stove Co.

Turnbull, Lance, East Liverpool, Ohio, Clay Products Salesman, Johnson-Porter Clay Co.

Waller, Alfred E., Lawrence Park, Bronxville, N. Y., Chief Engineer, Ward Leonard Electric Co.

Associate Foreign

Cote, A. U., Cooksville, Ontario, Canada, General Manager, Shale Brick Co.

Cuthbertson, M. R., Cerro de Pasco, Peru, S. A., Superintendent, Brick Plants.

Gardner, Wm., Hartington, Ontario, Canada, Gardner Feldspar Co.

Hesler, N. A., Montreal, Canada, General Manager, Consumers Glass Co. Ltd.

Jacobsen, Carl, 7 Malmogade, Copenhagen, Denmark, Professor in Ceramics, Technical High School.

Corporation

American Rolling Mill Co., Middletown, Ohio.

Charles Englehard, Inc., 30 Church St., New York City.

Whitall-Tatum Co., Millville, N. J.

The Art Division

The Art Division's activities have been chiefly those pertaining to organization and policy for the coming year.

Inquiries have been sent to active members and various officials in order to obtain their opinions and suggestions in regard to the general policy of the Art Division, as approved by the members at the meeting in Columbus.

The following Points have been discussed: 1. Acquisition of new members, 2. Research, 3. Exhibitions, 4. Industrial, 5. Educational, and 6. Publicity.

Directly these opinions and suggestions have been compared and classified, a summary will be submitted to the members of the Art Division for approval or criticism.

A considerable amount of work has been done pertaining to organization and the essential information. It is planned to begin active work early in July which will really be productive of results between that time and the next meeting.

(Signed): F. H. RHEAD, *Chairman*
M. C. FARREN, *Secretary*

Resolution to A. V. Bleininger.

Resolved; That the members of the Art Division, A. C. S. are in favor of a full time Secretary for the American Ceramic Society.

(Signed) F. H. RHEAD, *Chairman*
M. C. FARREN, *Secretary*

Heavy Clay Products Division

Report of the Joint Research Committee

American Face Brick Association.

The Common Brick Manufactures Association.

The Hollow Building Tile Association.

National Paving Brick Mfrs. Association.

Report No. 1 *June 16, 1921.*

Minutes of Executive Committee, Organization Meeting Held at Hotel LaSalle, Chicago, June 16, 1921.

In keeping with plans previously arranged, the chairman of the respective research committees of the four national associations of burned clay products manufacturers, named above, together with the secretaries of these associations, representatives of the Federal Government, universities, and the American Ceramic Society, met in Chicago on June 16th to perfect an organization through which the coöperation of the associations might be made effective in clay products research.

Those in attendance were—Messrs.:

P. H. Bates, U. S. Bureau of Standards.
A. V. Bleininger, Homer Laughlin China Co.
F. W. Butterworth, American Face Brick Assn.
M. B. Greenough, National Pav. Brick Mfrs. Assn.
R. D. T. Hollowell, American Face Brick Assn.
F. W. Lambert, Common Brick Mfrs. Assn.
R. B. Moore, U. S. Bureau of Mines.
R. C. Purdy, American Ceramic Society.
O. W. Renkert, Natl. Paving Brick Mfrs. Assn.
E. R. Sturtevant, Hollow Building Tile Assn.
E. W. Washburn, University of Illinois.

Mr. Hollowell, acting as Temporary Chairman called the meeting to order at 10:15 A.M.; The Executive Committee then proceeded to organize by the selection of these officers:

Chairman—F. W. Butterworth
Secretary-Treasurer—M. B. Greenough

Mr. A. V. Bleininger had already been selected as Chairman of the Technical Committee. He announced the members of his committee as follows:

A. V. Bleininger, *Chairman.*
R. H. Bates, U. S. Bureau of Standards, Washington.
R. C. Purdy, Am. Ceramic Society, Columbus, Ohio.
R. T. Stull, U. S. Bureau of Mines, Columbus, Ohio.
E. W. Washburn, University of Illinois, Urbana.

The Technical Committee then reported a plan of research which was approved by the Executive Committee in behalf of the four Associations.

The Chairman's presentation of the program is here quoted in full:

"The work will be divided into two parts—(1) Dealing with the study and investigation of commercial kilns, represented by the up-draft and the down-draft kilns, the continuous kiln of the straight tunnel type, the compartment continuous kiln and the tunnel car kiln. (2) Dealing with the study of the water-smoking and dehydration process, by the Bureau of Standards, the study of heat absorption throughout all the burning stages by the Ceramic

Department of the University of Illinois, the study of oxidation and vitrification stages by the Bureau of Mines, and experiments in the study of combustion and transmission of heat, in a semi-commercial kiln, by the Bureau of Mines at Columbus.

"The first part will constitute by far the most extensive part of the program and will involve the detailed study of the different types of kilns, not only from the standpoint of fuel consumption but particularly with reference to the rise of temperature throughout the kiln and the actual rates of water, smoking, oxidation and vitrification.

"It is proposed to study also the draft conditions, the combustion as taking place in different types of furnaces, the various heat losses, and the influence of the kiln, flue and stack dimensions upon the burning process.

"It is proposed that the Bureau of Mines send out well-trained experts to conduct this work at representative plants, selected for the purpose with special reference to securing a certain degree of freedom of action. By this is meant permission to be granted to make such burning changes as are apparent from the results obtained and to make notes of the effect of such changes. A complete study will be reported of each kiln examined, drawing from the observations made, all conclusions warranted by the facts.

"In addition, a questionnaire will be sent out by the committee to the industries concerned by means of which it is expected to obtain a certain amount of information which will help in drawing general conclusions.

"All of this information will be collected and treated from the standpoint not hitherto presented to the industries. It is expected to present the information collected by means of definite statements or definite recommendations in language that can be understood by all.

"The laboratory studies to be conducted at the Bureau of Standards and the University of Illinois are intended to furnish information concerning the methods of attack and the fundamental principles involved in the burning process and thus will supplement the kiln studies.

"In these investigations all purely theoretical features have been eliminated and only such work will be done as will throw direct light upon the phenomena involved in the burning process.

"Of particular interest will be the tests conducted on the semicommercial kiln to be erected by the Bureau of Mines at Columbus. In this kiln all the factors entering into combustion will be under control, such as the volume of air used for combustion, the intensity of the draft, the maximum and exit temperatures, and the rate at which the heat is transmitted to the ware. Thus it is expected to determine the effect of heavy or light fuel beds, the effect of long flame versus short flame coal, and other factors.

"It is to be noted, therefore, that the investigations will proceed along broad and comprehensive lines, and it is to be expected that the results will prove of interest and value to all of the ceramic industries.

"It is perhaps not too much to say that some of the results that may be expected will be of a more fundamental character than it is possible to realize

at the present time. It has always been the experience of such comprehensive investigations that many by-products, in the shape of important results that cannot be foreseen in the beginning, are obtained.

"The funds appropriated by the Heavy Clay Products Associations will be largely augmented by funds granted the Bureau of Mines by Congress and also by a contribution on the part of the Bureau of Standards. It is safe to say that the additional funds which will be made available are equal to at least twice and perhaps three times the amount contributed by the Associations."

In connection with the field studies of the Bureau of Mines, Mr. Bleininger emphasized the fact that permission would be sought to place men on various typical plants, to give them a free hand to conduct certain experiments upon representative kilns in process of burning, to follow up the effects of such experiments, and otherwise thoroughly to study the results of experimental operations. During the meeting, the facilities of the plants with which those present were connected, were tendered, and because of the value of the work, it is anticipated that ample numbers will thus be offered for experimentation.

In reference to a point raised by Mr. Lambert of the Common Brick Association, the meeting was assured that whatever steps were taken by the Technical Committee would be equally representative of the interests of each of the participating associations.

The Executive Committee voted to call a meeting of the entire membership of all the Association research committees about the middle of September, in Chicago, and there receive a progress report from the Technical Committee and to take such action as seems advisable at that time.

Adjourned 12:45. M. B. Greenough,
Secretary.

Organization of Joint Research Committee
and
Technical Committee

Contributing Associations

American Face Brick Association, R. D. T. Hollowell, Secretary, 110 South Dearborn Street, Chicago, Ill.

The Common Brick Manufacturing Association, Ralph P. Stoddard, Secretary, Schofield Building, Cleveland, Ohio.

The Hollow Building Tile Association, E. R. Sturtevant, Secretary, Conway Bldg., Chicago, Ill.

The National Paving Brick Manufacturers Association, Maurice B. Greenough, Secretary, 830 Engineers Building, Cleveland, Ohio.

Joint Research Committee

Chairman: F. W. Butterworth, Western Brick Co., Danville, Ill.

Secretary-Treasurer: M. B. Greenough, 830 Engineers Bldg., Cleveland, Ohio.

Face Brick Members

F. W. Butterworth (*Chairman*) (as above).

William C. Koch, Twin City Brick Co., Pioneer Building, St. Paul, Minn

F. T. Owens, Ridgway Brick Co., Watsontown, Pa.

Common Brick Members

Frank Lambert (*Chairman*), Illinois Brick Co., Chicago, Ill.

Warren Griffith, Baltimore Brick Co., 708 Maryland Trust Bldg., Baltimore, Md.

H. C. Klemeyer, Standard Brick Mfg. Co., Evansville, Ind.

Hollow Tile Members

J. J. Amos (*Chairman*), Humboldt Brick Mfg. Co., Humboldt, Kansas.

F. F. Anness, Anness & Potter Fire Clay Co., Woodbridge, N. J.

F. R. Hale, Vigo-American Clay Co., Terre Haute, Ind.

H. R. Straight, Adel Clay Products Co., Adel, Iowa.

Chas. G. Deckman, Medal Paving Brick Co., 16311 Saranac Rd., Cleveland, Ohio.

Paving Brick Members

O. W. Renkert (*Chairman*), Metropolitan Paving Brick Co., Canton, Ohio.

W. W. Cunningham, Clydesdale Brick & Stone Co., Jenkins Arcade Bldg., Pittsburgh, Pa.

W. H. Lucketberg, Burton-Townsend Brick Co., Zanesville, Ohio.

Eben Rodgers, Alton Brick Co., Alton, Ill.

C. A. Miller, Barr Clay Co., Streator, Ill.

J. R. Thomas, Standard Brick Corporation, Crawfordsville, Ind.

F. L. Manning, Peebles Paving Brick Co., Portsmouth, Ohio.

W. C. Brown, Southern Clay Mfg. Co., Chattanooga, Tenn.

A. W. Shulthis (Western P. B. M. Assoc. coöperating), First National Bank, Independence, Kans.

F. G. Matteson (Western P. B. M. Assoc. coöperating), Purington Paving Brick Co., Galesburg, Ill.

TECHNICAL COMMITTEE

A. V. Bleininger, *Chairman*, Homer Laughlin China Co., East Liverpool, Ohio.

P. H. Bates, U. S. Bureau of Standards, Washington, D. C.

R. C. Purdy, *Chairman*, Heavy Clay Products Division, American Ceramic Society, Columbus, Ohio.

R. T. Stull, U. S. Bureau of Mines, Experiment Station, Columbus, Ohio.

E. W. Washburn, Department of Ceramic Engineering, University of Illinois, Urbana, Ill.

EXECUTIVE COMMITTEE

F. W. Butterworth (*Chairman*), Frank Lambert, J. J. Amos, O. W. Renkert, R. D. T. Hollowell, R. P. Stoddard, E. R. Sturtevant, M. B. Greenough.

Preparation of Abstracts

Every article in THIS JOURNAL is to be preceded by an abstract prepared by the author and submitted by him with the manuscript. The abstract is intended to serve as an aid to the reader by furnishing an index and brief summary or preliminary survey of the contents of the article; it should be suitable for reprinting in an abstract journal so as to make a reabstracting of the article unnecessary. The abstract should, therefore, **summarize all new information completely and precisely.** Furthermore, in order to enable a reader to tell at a glance what the article is about and to enable an efficient index of its subject matter to be readily prepared, the abstract should contain **a set of subtitles** which together form a **complete and precise** index of the information contained in the article. This requires at least one and often several subtitles even for a short abstract.

In the preparation of abstracts, authors should be guided by the following rules, which are illustrated by the abstracts in THIS JOURNAL for February and March, 1921.* The **new information** contained in an article should first be determined by a careful analysis; then the subtitles should be formulated; and finally the text should be written and checked.

Rules

1. **Material not new** need not be analyzed or described in detail; a valuable summary of a previous work, however, should be noted with a statement indicating its nature and scope.

2. **The subtitles should together include all the new information**; that is every measurement, observation, method, improvement, suggestion and theory which is presented by the author as new and of value in itself.

3. **Each subtitle should describe the corresponding information so precisely** that the chance of any investigator being misled into thinking the article contains the particular information he desires when it does not, or vice-versa, may be small Such a title as "A note on blue glass," for example, is evidently too indefinite a description of information regarding "Absorption spectra of glass containing various amounts of copper-cobalt and chromium-cobalt." General subtitles, such as "Purpose" and "Results" should not be employed as they do not help to describe the specific information given in the article.

4. **The text should summarize the authors' conclusions and should transcribe numerical results of general interest,** including those that might be looked for in a table of physical and chemical constants, with an indication of the accuracy of each. It should give all the information that anyone, not a specialist in the particular field involved, might care to have in his note book.

5. **The text should be divided into as many paragraphs** as there are distinct subjects concerning which information is given, but no more than necessary. All parts of subtitles may be scattered through the text but the subject of each paragraph, however short, must be indicated at the beginning.

6. **Complete sentences** should be used except in the case of subtitles. The abstract should be made as readable as the necessary brevity will permit.

7. The ms. of all abstracts must be typewritten and double or triple spaced.

* The rules were prepared by the Research Information Service of the National Research Council. The Society is indebted to Dr. G. S. Fulcher of the Corning Glass Works (formerly with the National Research Council) for the rules and the illustrative abstracts.

OFFICERS, 1921-1922

President: F. K. Pence, American Encaustic Tile Co., Zanesville, Ohio.
Vice-President: Fred B. Ortman, Tropico Potteries, Inc., Glendale. Cal.
Treasurer: R. K. Hursh, University of Illinois, Urbana, Ill.
Secretary: C. F. Binns, Alfred University, Alfred, N. Y
Board of Trustees: The President, Vice-President, Treasurer, and R. M. Howe, M F Beecher, F. H. Riddle, R. H. Minton, and R T. Stull.

CORPORATION MEMBERS, 1920-1921

Abrasive Company.
Alexander Hamilton Inst.,
American Dressler Tunnel Kilns, Inc.
American Emery Wheel Works.
American Encaustic Tiling Co.
American Terra Cotta & Ceramic Co.

Bausch & Lomb Optical Co.
Beaver Falls Art Tile Co.

Bird and Company
Brick and Clay Record.
Buckeye Clay Pot Co.
W. G. Bush and Co.

Canton Stamping & Enameling Co.
Carborundum Co.
Champion Ignition Co.
Chicago Crucible Co.
Colonial Co.
Consolidated Window Glass Co.
Coonley Manufacturing Co.
Cortland Grinding Wheel Co.

Dings Magnetic Separator Co.
H. L. Dixon Co.
B. F. Drakenfeld & Co., Inc.
Dunn Wire Cut Lug Brick Co.
East Liverpool Potteries Co.
Edgar Plastic Kaolin Co.
Edward Ford Plate Glass Co.
Elyria Enameled Products Co.
Findlay Clay Pot Co.

French China Co.
Frink Pyrometer Co

W. S. George Pottery Co.
Gillinder Brothers.
Gleason-Tiebout Glass Co.
Golding Sons Co.

Hall China Co.
Hanovia Chemical & Mfg. Co.
Harbison-Walker Refractories Co
Harker Pottery Co.
Harshaw-Fuller & Goodwin Co.
Homer Laughlin China Co.
L. J. Houze Convex Glass Co.

Illinois Glass Co.

Jefferson Glass Co.
Jeffery-Dewitt Co.
Johnston Brokerage Co.
Jones Hollow Ware Co.

Edwin M Knowles China Co.
Knowles. Taylor and Knowles Co.
Laclede-Christy Clay Products Co.
Limoges China Co
A. J. Lindemann & Hoverson Co
Lindsay Light Co.
Los Angeles Pressed Brick Co
Louthan Manufacturing Co.

Macbeth-Evans Glass Co.
Maine Feldspar Co.
F. Q. Mason Color and Chemical Co.
Massillon Stone and Fire Brick Co.
Maxf Grinding Wheel Corporation.
Midland Terra Cotta Co.
Monongah Glass Co.
Mosaic Tile Co.
D. E. McNicol Pottery Co.
T. A. McNicol Pottery Co.

Nat'l. Fire Proofing Co.
Norton Co.

Ohio Pottery Co
Onondaga Pottery Co.
Owen China Co.

Pennsylvania Salt Mfg. Co.
Perth Amboy Tile Co.
Pfaudler Co.
Philadelphia Drying Machinery Co.
Phoenix Glass Co.
Pittsburgh High Voltage Insulator Co.
Pittsburgh Plate Glass Co.
Portland Stove Works.
Potters Supply Co.
Proctor & Schwartz, Inc.

Reliance Firebrick and Pottery Co., Ltd.
Roessler & Hasslacher Chemical Co.
Russell Engineering Co.

John H. Sant & Sons Co.
Saxon China Co.
Sebring Pottery Co.
Smith-Phillips China Co.
Standard Pottery Co.
Standard Sanitary Manufacturing Co.
Star Porcelain Co.
Steubenville Pottery Co.
Streator Clay Mfg. Co.
Square D. Co., Peru, Ind.

Taylor, Smith & Taylor Co.
R. Thomas & Sons Co.
Trenton Flint & Spar Co.

United States Glass Co.
United States Smelting Furnace Co.

Veritas Firing System.
Vitro Manufacturing Co.
Vodrey Pottery Co.

Warwick China Co.
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JOURNAL

OF THE

AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

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Vol. 4 July, 1921 No. 7

EDITORIAL

THE NEW SECRETARIAT

The long contemplated event has been consummated. The Society through its Board of Trustees has taken the step that should assure continued development along the line of larger service.

Under contract dated July 1 and approved by the Board of Trustees July 8, Mr. Ross C. Purdy was employed as Organizing Secretary for the remainder of the year. At the beginning of the ensuing year he will become the General Secretary of the Society in which office the duties covered by the term Organizing Secretary will also be absorbed.

This decision was reached only after careful consideration of expressions from the Society including a favorable report by the Committee appointed at the last annual meeting and communications from a large number of the Society's membership.

It is well known that many in close contact with the Society's problems have been looking forward to the time when the employment of a full-time Secretary could be undertaken. They have regarded the creation of this office as an event in the normal program of development. This move is not one in which spectacular membership campaigning, or mushroom activities

will be a feature. The office has been created largely to meet a need that is already being made manifest by requests coming from organizations of industries themselves, indicating a service in which the Society must at once take leadership or jeopardize rightful position in its relation to the clay industries. I refer to the field that may be included under the term Coöperative Research. From this field the Divisions that flourish must draw their sustenance. Perhaps in some instances this must also provide new life to Local Sections.

The duties of the Secretary are not confined to the activity above emphasized, his duties being those prescribed by the special committee, later including those of general secretary, also "Such other duties as may be from time to time prescribed."

In the creation of this office the Society should be able to properly organize and supervise its underlying and fundamental activities. This, done in proper relationship with the industries, the problems of membership, finance, contributions to the Journal, and general interest and support, will find ready solution.

In forwarding this most important service the Society is very fortunate in securing the services of Mr. Purdy, who in the words of the special committee, "possesses the necessary qualifications of ability, leadership, zeal and energy to the fullest extent."

However, let no one of our members and officers presume that the burden of responsibility to the Society is lessened. The same necessity for personal interest, and devotion of thought and effort exists as before. The Society now has employed under the direction of the Board of Trustees an agency whereby the power to do and to serve is markedly increased.

The earnest coöperation of all concerned will enable the Society to rise to new and higher standards of attainment.

F. K. PENCE

PLANS OF THE NEW SECRETARY

In response to the requirements of the times and the expressed desire of the Society, the Board of Trustees has employed a Secretary to serve the remainder of this calendar year as Organizing, and next year as General Secretary. The object of employing an Organizing Secretary is none other, neither more nor less, than the object for which the Society was founded, and for which, for twenty-two years, it has been maintained:—"to advance the ceramic arts and sciences."

The organizing work of this secretary, as distinct from that which Prof. Binns is so efficiently doing, can be generalized in the words of the special committee in its report to the Board of Trustees, which report was accepted, and approved, and the section under caption—"Duties of the proposed permanent Secretary"—made a part of the contract of employment.

These, in part, are:

It should be the duty of the Organizing Secretary to assist the officers of the divisions in planning the work and executing the tasks undertaken. He should report to the Board of Trustees upon the status of the divisions at the expiration of every quarter. He should be charged with the duty of supporting and supplementing the work of the Committee on Membership and may be authorized by the Board of Trustees to undertake and prosecute such additional measures which promise to increase the membership of the Society, both individual and corporate.

It should be the duty of the Organizing Secretary to assist the Committee on Papers and Program in securing contributions of merit and in every way possible, to aid in improving the program of the meetings and bringing before the membership topics of vital and timely interest.

It should be the duty of the Organizing Secretary to work towards the establishment of coöperative researches, conducted under the auspices of the divisions of the Society, and supported by associations or groups of manufacturers, or single corporations. He should be charged with the duty of preparing research agreements, subject to the approval of the Board of Trustees. All disbursements made from funds made available to the Society for research purposes should be made by the Treasurer.

It should be the duty of the Organizing Secretary to aid the Division Officers in formulating research problems. It should be his duty likewise to supervise the prosecution, reporting, and publication of such researches, unless other supervision is provided for by the Division of the Society, and to report to the Board of Trustees, upon the progress of such work monthly.

It should be the the duty of the Organizing Secretary to maintain friendly relations with the associations of manufacturers and similar organizations, to address them on the subject of the work of the Society and related topics and to secure their coöperation in our several fields of endeavor.

This officer should be charged also with the duty of assisting in the preparation for meetings of the Society, the securing of suitable quarters and necessary equipment.

It is important to note that the scope of the Organizing Secretary's authority in all these matters is limited to "assisting," "supplementing," "supporting" and "aiding." He is to encourage, promote and execute only by the authority of, in the name of, and through the Board, the Committees, the Local Sections or the Divisions, as each case will require. In other words, he is merely to assist, support, aid and supplement the existing agencies already provided for by the Constitution and By-Laws.

The Organizing Secretary is a representative of the Board of Trustees, and therefore, such authority as may be possessed by him shall be only that granted to him by the Board. This same limitation is placed on all the executive officers of the Society: the President having "general supervision of the affairs of the Society under the direction of the Board of Trustees,"—and—"can countersign checks drawn by the Treasurer when such drafts are known by him to be proper and duly authorized by the Board of Trustees."

The Standing Committees, Local Sections and Divisions have duties and authorities given by the Constitution and By-Laws that are their own, and of kinds that are wholly apart and distinct from those possessed by the Board. But, the Constitution says that "on failure of any officer or any member of a committee to execute his duties within a reasonable time, the Board of Trustees, after duly warning such person, may declare the office vacant and appoint a new incumbent." With the possession of this authority on part of the Board there is a corresponding responsibility of seeing to it that the Committees, Local Sections and Divisions perform their tasks, hence it is well that the Board, through its representative, the Organizing Secretary, shall "assist," "advise" and "supplement" in whatever is undertaken by the Committees, Sections and Divisions.

By the appointment of an Organizing Secretary to serve in the capacity of an assisting and supporting supervisor of the work of the Committees, Sections and Divisions, the Board of Trustees, for the first time, has a means of coördinating and unifying the work of the entire organization on the one general program of advancing the ceramic arts and sciences. That distribution of responsibilities, and those unrepressed and unstinted opportunities for service by each independent unit in the organization, which should and which do characterize this Society, is in no way curtailed. On the other hand, there is assured, as far as it is humanly possible so to do, to each Industrial Division, Section and Committee, that freedom of development along lines of its own choosing, which is so essential to holding the interest of, and obtaining the full support of, the individual members without danger of any of them losing sight of the common interests and mutual purposes for which they have joined together in support of the Society as a whole.

Emphasis should be placed on the fact that the Organizing Secretary can not and will not relieve the Committeemen or the Officers of the Local Sections, and Divisions, of their responsibilities. The limit of the Secretary's activities is assisting, supporting and promoting; in other words, a general supervision of the technical work of the Society.

The Board is more concerned with the general business of the Society, while the Committees, Sections and Divisions are engaged in specific fields more directly concerned with attaining the ultimate object of the Society, that of "advancement of the ceramic arts and sciences." This division of responsibilities gives the Society two groups of executive officers, (1) the general supervising and managing (the Board) and (2) the technical (Committees, Sections and Divisions).

The need is recognized for the full time service of an officer to assist the Committees, Sections and Divisions (not to do their work) in such service as will build the Society up to the strength and the position of being recognized by the ceramic industries and by the other technical associations, and the Bureaus and Colleges as the pivotal unit, the prime mover in the promo-

tion of ceramic arts and sciences as it was in the earlier years under less developed conditions. This necessitates the keeping of each and every member in close working contact with the Society, and the Society, in turn, in close working understanding with the other ceramic associations and the users of ceramic products, coöperation with other national technical organizations in those endeavors in which the ceramic groups have reason to be interested.

One such activity is coöperative research. Research financed by associated corporations is in vogue today, whereas in former years the industries supported general ceramic research without regard to special applications. As the industries progressed in things technical, they learned the value of joining by groups in financial support of researches in which they were particularly interested. Thus their support of and interest in scientific and technical research gradually shifted from general to specialized investigations. The advantages of group specialization, emphasized as they were by war conditions, was recognized by the American Ceramic Society through its establishment of Industrial Divisions.

These Divisions have succeeded or failed according to the quality and the continuity of executive attention given by the Division Officers, and also according to the extent to which they have enlisted their particular group of manufacturers in the support of scientific and technical research. It is to correct these shortcomings that the Organizing Secretary was appointed, for the success or failure of the Divisions is the success or failure of the Society as a whole in serving the different groups of ceramic industries.

The American Ceramic Society has been and will continue to be the principal agency for the advancement of ceramic arts and science. In the early days when there was but the one collegiate department of ceramics, no federal bureaus, and when the manufacturers were jealous of their trade secrets, Prof. Edward Orton, Jr. did a great service to the Ceramic Industries when he persuaded a few ceramic workers to join in the founding of the American Ceramic Society. Since 1899 this Society has continued steadfast to its original purpose, and was and is de-

serving, and enjoying the support of the Ceramic Industries with the result that today our Industries are second to none and equal to any in the world in technical attainments.

It is intended that this Society shall continue as the leading agent for the advancement of Ceramic Technology, and it is assured that each Division will enjoy in this purpose the full coöperation and backing of its respective group of manufacturers with the same zeal and for the same purposes with which, in previous years, the Society as a whole was supported.

That all this may be realized and thus the purposes and hopes of Prof. Orton and his collaborators carried to full fruition, the Board of Trustees has elected a full time Secretary and given emphasis to the organizing duties as distinct from the routine, and it is to the carrying through of this program that I, the elected Secretary, pledge my ability, zeal and singleness of purpose, and it is to this that the full coöperation of each and every member of the Society is asked.

Ross C. Purdy

ORIGINAL PAPERS AND DISCUSSIONS

THE COMPOSITION OF BARIUM GLASS[1]

By Robert J. Montgomery

ABSTRACT

In this paper the relation between the composition of barium glasses and the optical constants is discussed as well as the general rules for proportioning batches. The important results and conclusions are given by the figures. After the required amounts of BaO and B_2O_3 have been obtained from figures 2 and 3, the amount of SiO_2 can be obtained from figure 5, the alkali and ZnO from figure 7 and the Al_2O_3 from figure 8. If the total exceeds 100, the ZnO and the Al_2O_3 may be reduced. The proportions cannot be as definitely expressed as in the case of lead glasses and more experience is required to enable one to change the optical properties at will.

Introduction

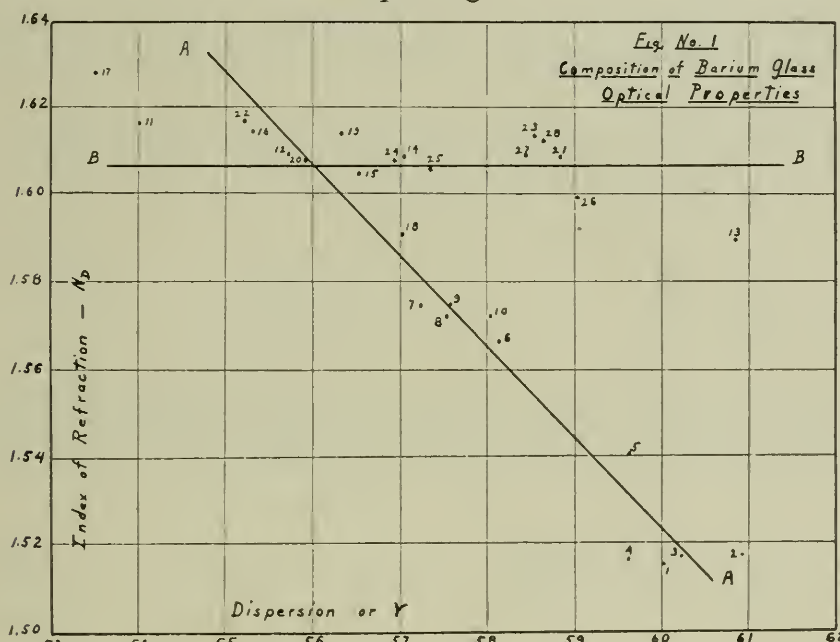
In a previous paper,[2] the optical glasses whose main component is lead were discussed. The present paper covers another section of the optical glass field and includes those glasses whose properties are dominated by their barium oxide content. The composition of barium glasses is not as easily covered as that of lead glasses, because of the greater complexity of the batch. With lead glass we have essentially a three component system of alkali, lead and silica, while in barium glasses we have a second acid (B_2O_3) introduced, as well as Al_2O_3 and a more comlpicated RO containing zinc and calcium in addition to alkali and barium. The zone covering the relation of optical properties to composition, which is narrow in the case of the lead glasses, is here much wider with a dispersion, as expressed by the ν value, ranging from 54 to 61 and an index of refraction for the D line, from 1.50 to 1.63. The composition is further complicated by the use of lead in the baryta flint

[1] Received April 2, 1921.

[2] This Journal, 3, 900 (1910)

glasses. These lie between the typical barium glasses and the lead glasses proper and their composition will not be discussed in this paper. In the paper on lead glasses referred to above the compositions were discussed on the equivalent weight basis because of their simplicity. With barium glasses it was found that little or nothing was gained by employing the equivalent weight basis because of the complexity of the glasses. There are no simple relations between composition and optical properties and the relations observed have to be expressed in more general terms. For this reason the composition will be given in weight per cents

$$\nu = \frac{N_D - 1}{N_F - N_C}$$



of the oxides present. The optical properties referred to are the refractive index for the D line, N_D, and the reciprocal dispersion or constringence ν, defined by the equation.

In figure 1 are plotted the optical properties of 28 typical barium glasses whose compositions are given in table 1. These extend from the ordinary crown glass as a base through the barium silicate crowns, and the dense barium crowns to the densest barium crown. The relation of these glasses to the general field may be seen by referring to the chart given in a previous paper.[1] The baryta

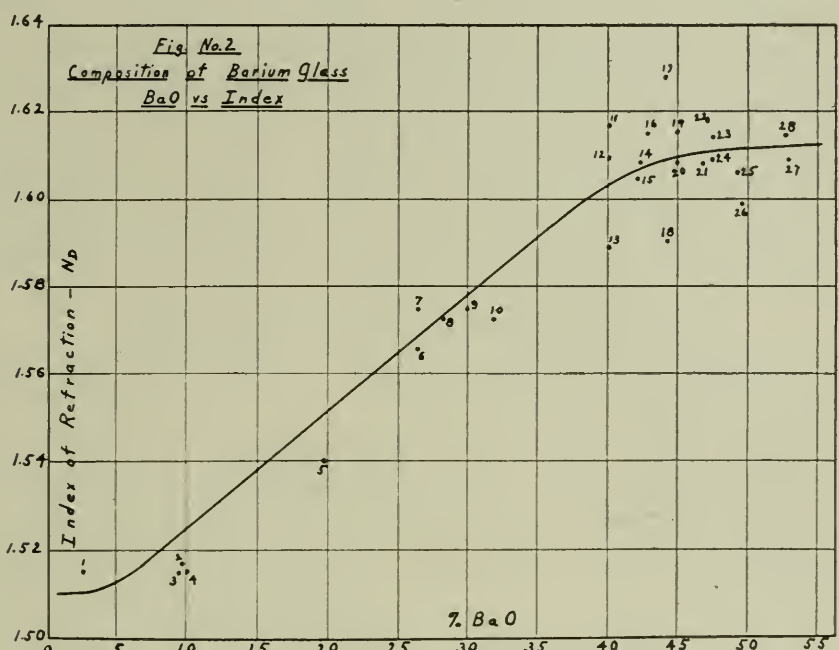
[1] This Journal, **3**, 404–10(1920).

TABLE I

No.	SiO_2	B_2O_3	K_2O	NaO	BaO	CaO	ZnO	As_2O_3	Al_2O_3	PbO	N_D	ν
1	71.56	...	9.01	8.08	2.61	8.02	...	0.72	...	...	1.5160	60.0
2	68.50	3.50	5.00	12.00	9.70	...	1.00	0.20	...	...	1.5179	60.9
3	64.60	2.70	15.00	5.00	10.20	...	2.00	0.40	...	...	1.5179	60.2
4	67.00	3.50	5.00	12.00	10.60	...	1.50	0.40	...	...	1.5171	59.6
5	59.13	3.04	9.70	3.16	19.25	0.13	5.00	0.34	0.11	...	1.5409	59.6
6	49.57	4.51	8.49	1.01	26.06	...	10.03	0.34	...	...	1.5666	58.1
7	48.10	4.60	8.00	2.00	26.05	2.00	8.40	0.50	...	...	1.5755	57.2
8	48.10	4.50	7.50	1.00	28.30	...	10.10	0.40	...	...	1.5726	57.5
9	48.00	4.50	6.10	2.00	29.50	...	10.00	1.40	...	...	1.5754	57.5
10	48.45	3.65	7.55	0.95	32.63	...	6.46	0.32	...	...	1.5727	58.0
11	37.23	6.02	...	3.19	40.40	...	10.79	0.37	1.98	...	1.6167	54.0
12	37.30	6.00	...	3.20	40.50	...	10.80	...	2.00	...	1.6097	55.7
13	37.50	15.00	...	...	41.00	...	...	...	5.00	...	1.5899	60.8
14	34.50	10.10	...	...	42.00	...	7.80	0.50	5.00	...	1.6088	57.0
15	39.63	6.04	...	...	42.08	...	9.24	0.50	2.50	...	1.6054	56.5
16	36.28	5.57	3.20	...	43.62	0.21	10.73	0.39	...	...	1.6147	55.3
17	37.00	5.00	2.60	...	44.00	...	7.70	0.70	...	3.00	1.6242	53.5
18	39.60	5.00	...	...	44.00	2.00	7.70	0.40	...	3.00	1.5905	57.0
19	39.00	5.00	...	...	45.00	2.60	7.00	0.40	1.00	...	1.6145	56.3
20	37.80	5.69	3.50	...	45.04	...	7.56	0.40	...	...	1.6085	55.9
21	34.56	10.96	0.09	0.21	46.91	...	1.14	0.59	5.02	...	1.6091	58.8
22	37.00	5.00	2.60	...	47.00	...	7.70	0.70	...	...	1.6177	55.2
23	32.27	12.90	0.33	...	47.20	...	1.12	0.20	6.10	...	1.6139	58.5
24	38.29	5.76	2.84	...	47.60	...	5.11	0.41	...	...	1.6085	56.9
25	38.12	7.18	2.40	...	49.37	...	2.54	0.41	...	...	1.6062	57.3
26	36.58	11.60	0.10	0.22	49.66	...	1.21	0.62	...	...	1.5991	59.0
27	36.46	8.91	1.21	...	52.88	...	...	0.39	...	...	1.6091	58.4
28	36.51	8.93	1.22	...	52.96	...	...	0.39	...	...	1.6138	58.6

References—C. N. Fenner, THIS JOURNAL, **2**, 102(1919).
Williams and Rand, *Ibid*, **2**, 422(1919).
Allen and Zies, *Ibid*, **1**, 739(1918); Doelter's "Handbuch der Mineralchemie."

light flint, telescope flint and soft silicate crown are omitted because of the lead content although they contain considerable barium. Only one barium silicate crown glass was available but the others used are selected from a great many obtained from experimental melts in our plant, and from published information. On first consideration the scattered positions of the points seem to show little regularity. A further study reveals certain underlying relations and these will now be discussed.



BaO vs. Optical Properties

When it is desired to increase the index of refraction in a soda-lime glass without lowering the ν value, barium is used. The dispersion is not affected to any extent by the barium and we may have more than 40 per cent BaO in glasses whose ν values vary only from 53 to 60. The line A-A in figure 1 shows the effect of the addition of barium to a soda-lime glass. The ν value decreases not because of the increased barium but because of the decrease in SiO_2 which the barium displaces. The normal index of refraction of a soda-lime glass is about 1.51, largely due to its content of silica which has an index of 1.4585. It may be raised as high as 1.52 to 1.53 by the addition of lime, but above this point we have to

resort to barium if the ν value is not to be lowered. The relation between the increase of index and the barium content is very nearly a straight line as the barium increases up to 40 or 42 per cent. This relation is shown graphically in figure 2. Above 42 and up to 54 per cent, which is about the maximum in these glasses, very little change in index is noted, the line becoming practically horizontal. The points do not lie as closely to the line as could be wished, but as the index is affected by the other constituents the variation is not unexpected. Glass number 17 contains 3 per cent of PbO which is responsible for its rather high index. Barium cannot be studied without the introduction of B_2O_3, since with the higher per cents of BaO, boric acid is necessary in order to prevent crystallization on cooling. The effect of B_2O_3 will therefore be shown next in conjunction with SiO_2 as both have to be considered together in a discussion of optical properties.

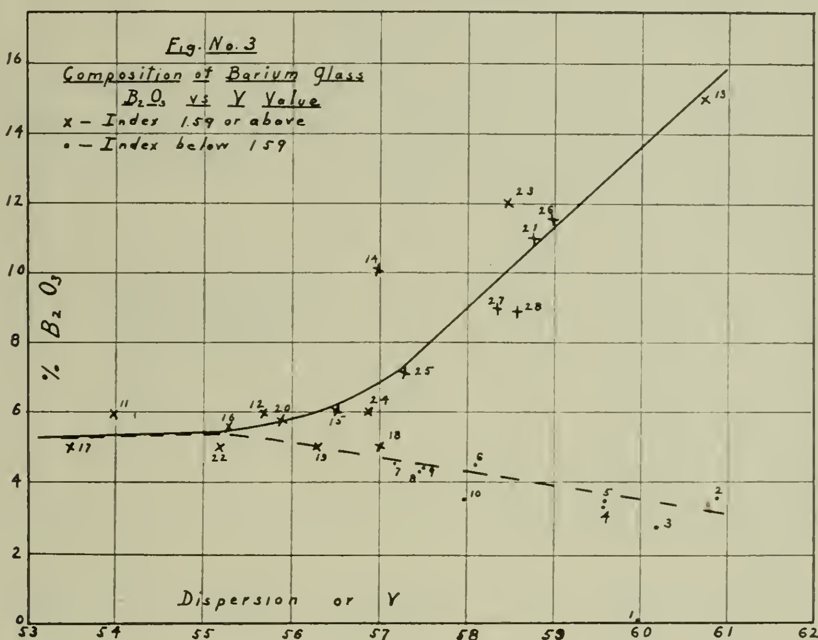
B_2O_3 and SiO_2 vs. Optical Properties

In considering the effect of these two materials their optical properties must be kept in mind. They are as follows: Boric acid glass N_D 1.463, ν 59.4; Silica glass N_D 1.4585, ν 67.9.

Their influence on the optical properties of glass are quite consistent except in one case. In a high BaO glass, SiO_2 will lower the index more than will B_2O_3. For some unknown reason an addition of B_2O_3 will often *raise* the index of refraction in both barium and lead glasses when the index is about 1.60. It very seldom causes a drop in index although the index of boric acid glass is low.

Soda-lime glasses and glasses of this general type containing small amounts of barium are dominated by the properties of silica, and have an index of about 1.518 and a ν value of about 58 to 60. The effect on the dispersion, of the B_2O_3 which may be present up to 5 per cent, is not noticeable. In the glasses high in BaO, which have a correspondingly low SiO_2 content, the effect of B_2O_3 is more easily seen. It is quite apparent when the index is 1.59 or above. The line B-B in figure 1 shows the tendency of B_2O_3 to increase the ν value when the SiO_2 content is constant. In figure 3 the relation between B_2O_3 and the dispersion is given. Glasses with an index of 1.59 or above are indicated by crosses and the heavy line curve passes through these points. The

glasses containing less than 6 per cent B_2O_3 evidently fall into another group indicating that the higher ν value may be obtained with silica as well as with B_2O_3. A dash line passes through this group. The variation in dispersion is evidently limited by the optical properties of SiO_2 and B_2O_3 and the amount of each which can be introduced into a commercial glass.



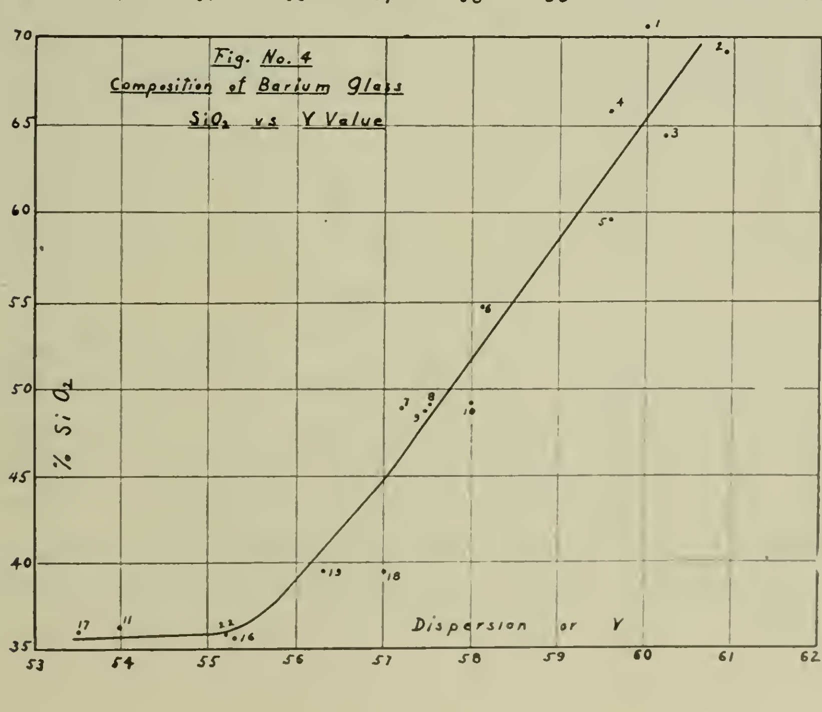
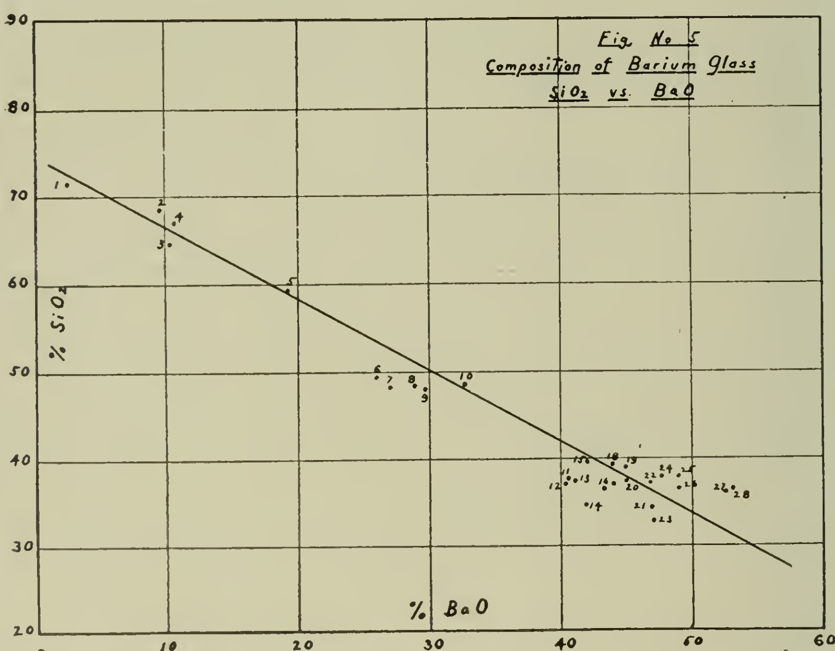


Figure 4 shows the relation between SiO_2 and the ν value in those glasses containing less than 6 per cent B_2O_3. This includes the group through which the dash line is drawn in figure 3.

There are a number of general relations referring to the proportioning of the constituents of the batches which may be shown in curve form. These are as follows:

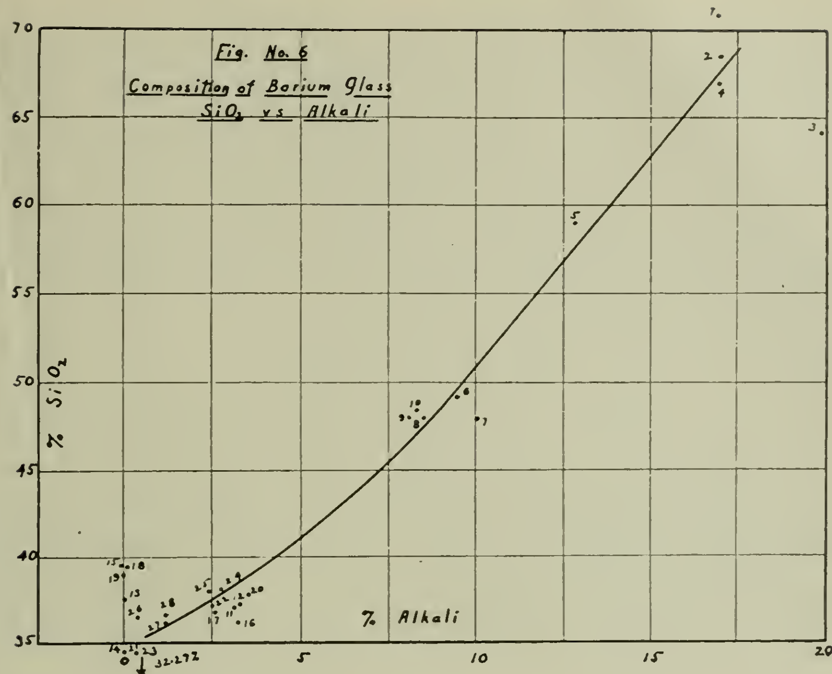
SiO_2 vs. BaO

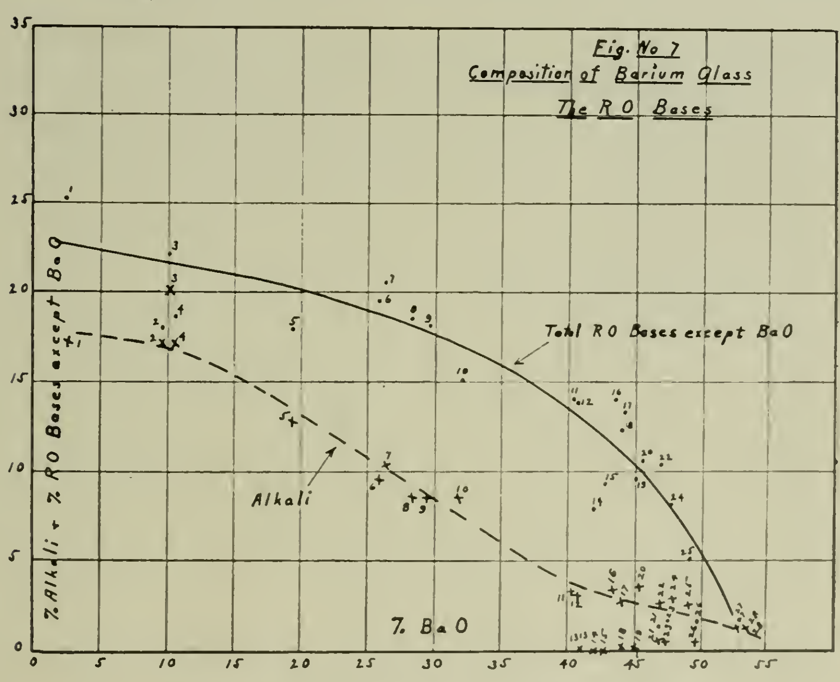
The relation between the barium and silica content is clearly shown in figure 5. The required proportions are quite well defined, a decided drop in the silica content as the barium increases being noticeable.



SiO_2 vs. Alkali

As would be supposed, the amount of alkali in the glass increases with the silica. The curve in figure 6 shows this relation. While the points are not all very close to the curve drawn the general relation is beyond question. It must be remembered that in these complex barium glasses a comparison of any two constituents will be affected, often to a considerable extent, by the other constituents present. Only general relations can be established.





The Proportioning of the RO Bases

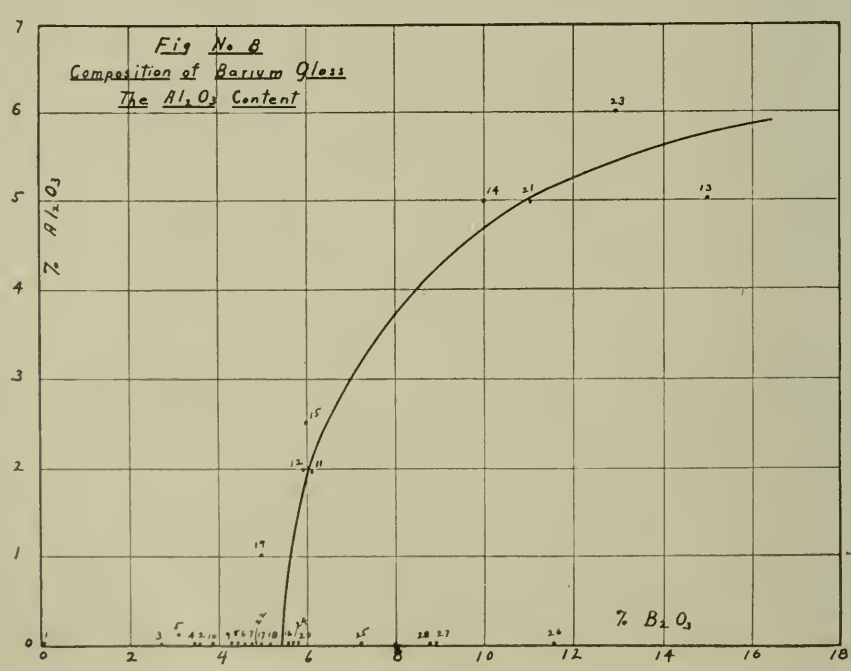
In figure 7 the relation between BaO and the other RO bases is shown. The solid line goes through the total RO bases except BaO and includes K_2O, Na_2O, CaO, ZnO and PbO. The dash

line runs through the points representing the alkali content including K_2O and Na_2O. The positions of the two curves are fairly well defined except when the BaO is over 40 per cent. Some of the the glasses contain no alkali while others contain 2 to 3 per cent. Alkali is not necessary to obtain the desired optical properties and when used it is for the purpose of controlling the melting and working properties of the glass.

The Al_2O_3 Content

It is hard to determine just what the Al_2O_3 content depends on. It is not necessary to use alumina to control the optical properties but it is almost invariably used and the amount seems to depend upon the B_2O_3 content, at least an interesting comparison can be obtained between the amounts of these two constituents. Alumina would tend to increase the viscosity of the glass and reduce the attack upon the pot.

In figure 8 the Al_2O_3 and B_2O_3 contents are plotted against each other and an average curve is given. Al_2O_3 is seldom used until the glass contains at least 5 per cent B_2O_3 and then it increases quite rapidly with the addition of B_2O_3 reaching a maximum at about 6 per



cent. Points 25, 26, 27, and 28 are not on the curve and they are rather abnormal in this respect. They prove that the optical properties do not depend upon the Al_2O_3.

The ZnO Content

Zinc oxide may run as high as 11.0 per cent in these glasses but it has little effect upon the optical properties. It is used largely to fill in when it is undesirable to increase any of the other constituents. Zinc oxide may replace BaO to lower the index of refraction or replace B_2O_3 to lower the ν value.

Alkali

Potassium is the alkali almost invariably used because the sodium compounds give greater color. The amount used depends upon the flux required after the SiO_2, BaO, B_2O_3 contents are adjusted to give the proper optical constants.

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ROCHESTER, N. Y.

THE METALLOGRAPHY OF THE OXY-ACETYLENE WELD AS AFFECTED BY ENAMELING[1]

E. P. Poste

ABSTRACT

Metallography of Low Carbon Steel.—A discussion of the cooling of steel through the critical range is followed by a consideration of the general structure of low carbon material. A brief discussion of mechanical and thermal treatments follows including the statement of the essential conditions for annealing.

Investigation of Oxy-Acetylene Welds.—The temperature reached by the steel in the enameling operation is discussed with reference to the annealing temperature. An examination of plates and welds before and after enameling shows that a thorough annealing of the weld has been accomplished.

Although the subject of metallography is undoubtedly new to the average enamel technologist, it will only be possible to very briefly cover some of the fundamentals before taking up the experimental work being covered by this paper. If the reader is interested in a more complete consideration of the principles of metallography, he will be able to make use of the following references:

The Metallography and Heat Treatment of Iron and Steel—Sauveur.
Metallography of Steel and Cast Iron—Howe.
Chemistry of Materials—Leighou. Pages 102–118.

Metallography of Low Carbon Steel

Steel is essentially an alloy of iron and carbon produced by certain definite metallurgical processes. In the melted condition, it consists of molten iron holding the carbon in solution. After solidification the mass assumes certain crystalline forms which undergo definite changes in cooling through what is termed the critical range, from approximately 900 to 770°C (1650 to 1420°F). After cooling below this range the steel is found to be made up of two substances termed "ferrite" and "pearlite;" the former is iron, while the latter is a definite combination of iron and carbon.

Confining our discussion to low carbon steels such as are used in enameling, it should be noted that the amount of ferrite greatly

[1] Received March 1, 1921.

predominates over the pearlite and a carefully polished and etched specimen observed under the microscope will show in general a net-work of more or less regular polygons of ferrite between which are areas of pearlite.

The structure just described is the normal structure existing after slow cooling. If the metal is cooled more quickly through the critical range or is worked upon mechanically at or below the critical range, the resulting structure may be materially different. Further, if metal originally below the critical range is heated to or above its critical range and recooled or worked mechanically and recooled, a great variety of results is possible. This general principle is the basis of all mechanical and thermal treatment of steel including hardening, tempering, annealing and similar operations.

The critical temperature of steel varies with the carbon content, the greater the percent of carbon the lower the temperature. It follows from this, therefore, that the temperature to which the piece must be raised to effect various types of heat treatment, such as annealing, must be in general slightly above the critical temperature for steel of the particular carbon content involved.

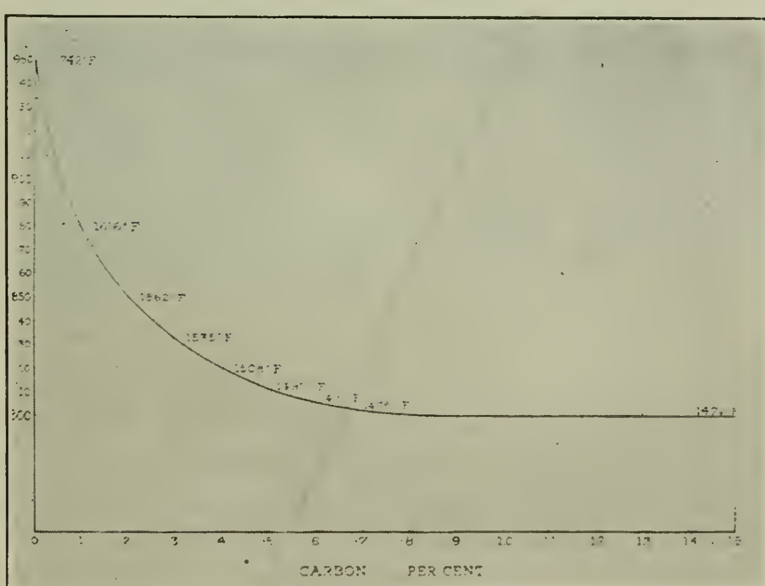

Fig. 1.—Annealing temperatures of steel. See "Metallography and Heat Treatment of Iron and Steel"—Sauveur. Page 234.

Figure 1 shows the minimum annealing temperature for the various carbon steels. With particular reference to the steel used in enameling, which generally falls between 0.10 and 0.20 carbon, it will be noted that the minimum annealing temperatures range from 880 to 850°C (1616 to 1562°F).

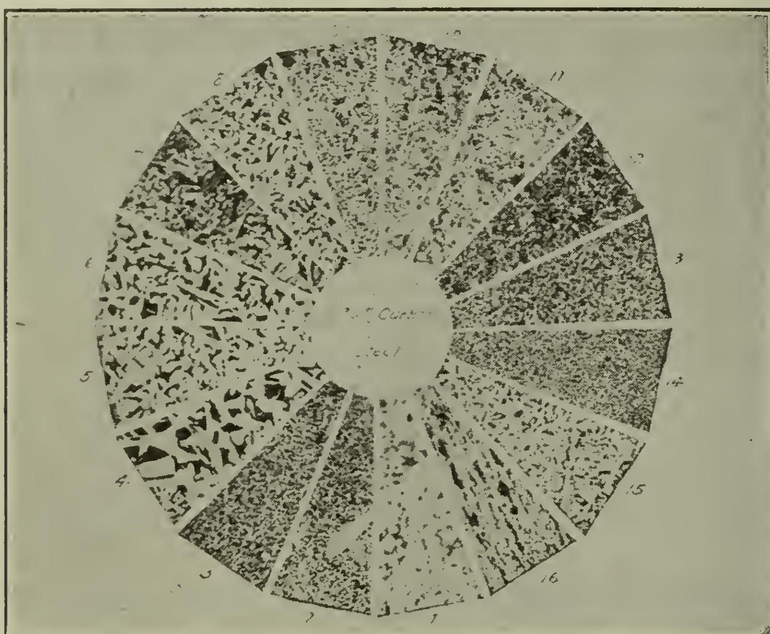

FIG. 2.—Various structures of 0.30% carbon steel. See "Metallography and Heat Treatment of Iron and Steel"—Sauveur. Page 253.

Figure 2 shows various possible variations in the structure of 0.30% carbon steel. Number 4 represents a very large grained structure produced by certain definite mechanical and thermal treatment while number 14 represents the other extreme of structure produced by another set of mechanical and thermal conditions. Numbers 1, 10 and 11 illustrate some indefinite structures similar to those which will be observed later in connection with the experimental work. Number 16 shows cold worked metal with "banded" structure similar to that which will be mentioned later.

In general a fine grained even structure is more ductile than a course or uneven structure; for instance number 14 in figure 2 is the desirable structure in a 1/2 inch round rolled bar while numbers 5, 8, 9, 10, 11 and 12 are less desirable structures in the same bar.

Investigation of Oxy-Acetylene Welds

Various observations in connection with the firing of enameled tanks have long indicated that the enameling operation involves the heating of the tanks to a sufficiently high temperature to effect the annealing of the welds. It has been only recently that this matter has been investigated from a metallographic point of view and the results are well worth recording.

FIG. 3.—Welded plates showing zones of color.

By means of an optical pyrometer, careful measurements have been made as to the actual temperatures reached by the steel in the enameling furnaces. It has been observed that on leaving the furnace the steel temperature ranges from 900 to 950°C (1650 to 1750°F), varying somewhat with different enamels. Referring to the curve indicating the necessary annealing temperature for steels, it will be noted that any steel which would be used for enameling would be at a safe annealing temperature when above

880°C (1620°F). Effort has been made to determine the total time at which a tank undergoing the normal enameling operation would be at a temperature above 900°C (1650°F) and a very reasonable approximation indicates that this time is 15 minutes. From a purely theoretical point of view this should produce a very thorough annealing. Considerable experimental work to support this, however, has been carried on and some typical observations will be reviewed.

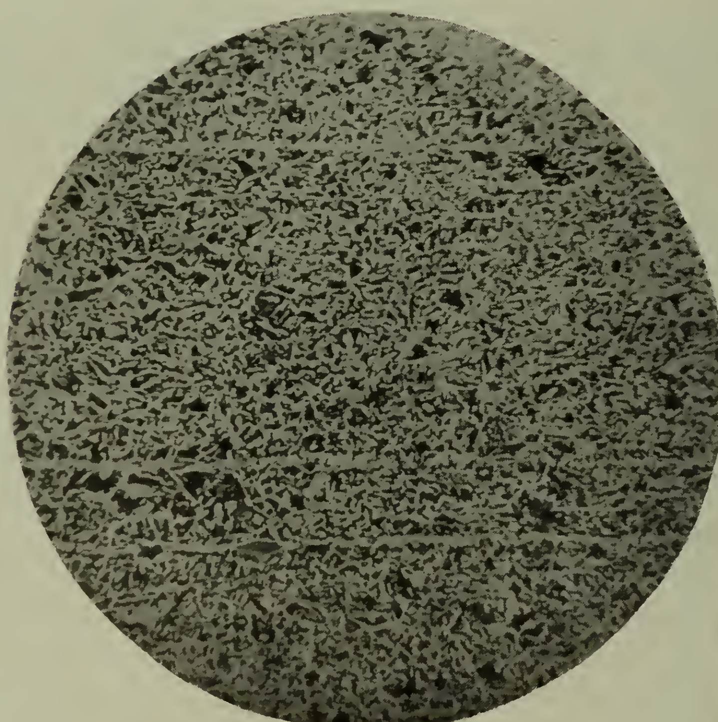

Fig. 4.—Structure of plate 10″ from weld.

Two sheets of steel (approximately 0.15% carbon), one foot wide and 2 feet long, were sand blasted and welded together after the usual beveling of the edges. The removal of the mill scale by the sand blast before welding made possible an interesting observation as to the color effect produced by the welding.

Figure 3 shows the weld very distinctly as well as the color effects in the adjacent steel. Starting at the edge of the steel away from the weld, the color is that of sand-blasted steel up to a point approximately 5″ from the center of the weld where the

color works through the usual straw colors up to the deep blue and purple characteristic of steel heated to the corresponding temperatures. The general extent of these influences is obvious from the figure.

The weld was ground smooth on either side and for experimental work several strips 1″ wide were sawed out perpendicular to the weld. Metallographic specimens were prepared covering the entire range of heat conditions.

Figure 4 shows the structure of the metal about 10″ from the weld, obviously well beyond the influence of the heating. It will be noted that the structure is that of a plate worked slightly below its critical temperature as evidenced by the tendency for banding.[1]

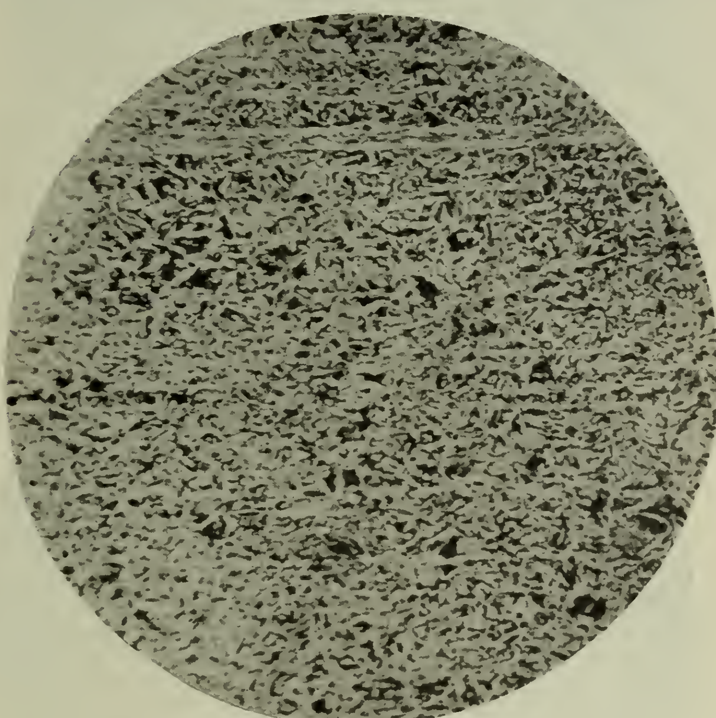

FIG. 5.—Structure of plate 4″ from weld.

Figure 5 was taken at the edge of the straw color, approximately 4″ from the center of the weld. The banded structure is still apparent though possibly slightly less pronounced. Figure 6 was taken at the point of most intense blue color 2 $^3/_4$″ from the weld and the banded structure is but slightly noticeable. Figure 7 was

[1] See figure 2—number 16.

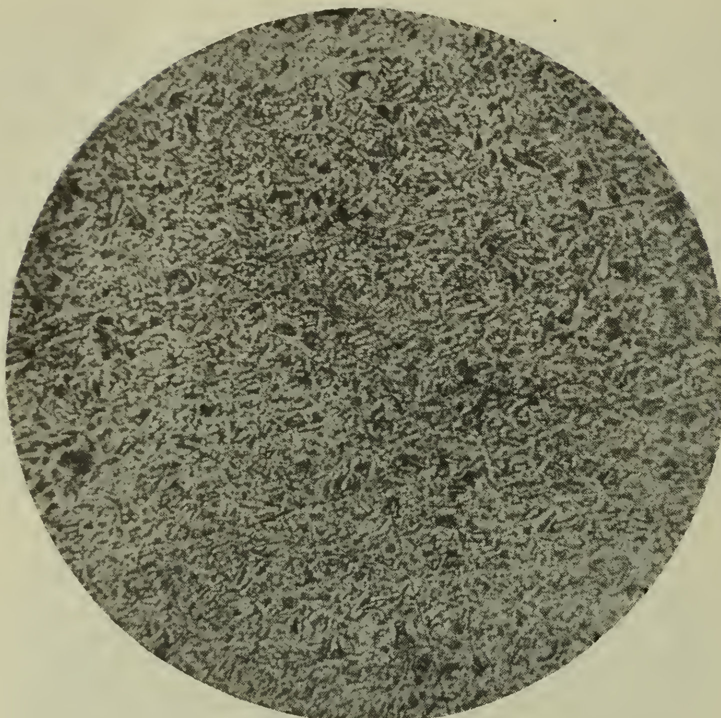

FIG. 6.—Structure of plate $2^3/_4''$ from weld.

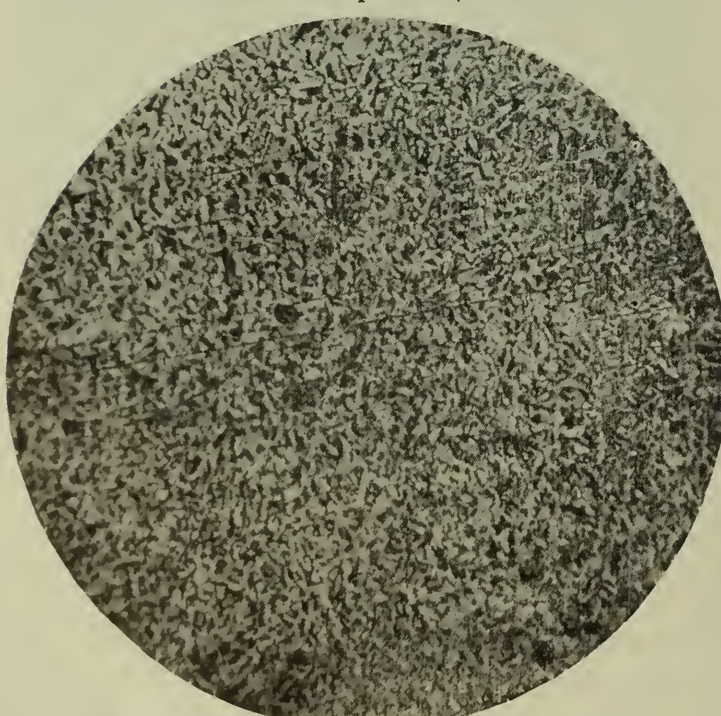

FIG. 7.—Structure of plate $1^1/_2''$ from weld.

taken inside the maximum blue line $1\,^1/_2''$ from the weld and the banded structure is practically eliminated.

Figure 8 shows the structure of the filler run in between the plates. This filler shows on analysis about 0.05% carbon. It has the normal structure of low carbon iron. Very minute areas of pearlite can be detected here and there.

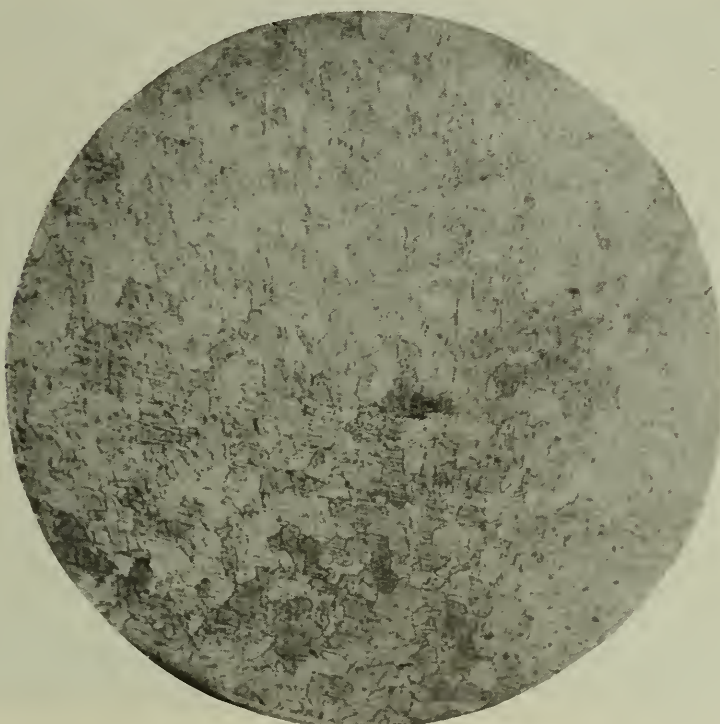

FIG. 8.—Structure of filler.

Figure 9 shows the junction between the plate and the filler. At the extreme right of the figure is seen a structure essentially the same as that of figure 8. The major portion of the figure, however, indicates the coarse irregular structure which has been produced by the intense heating of the plate above its critical temperature. It is interesting to compare this structure with that given as typical of electrically welded sheets on page 12, figure 2, Catalog of the H. M. Kellog Co. This structure also compares very favorably with that shown in figure A, on page 123 of Hoyt's "Principles of Metallography." Hoyt terms this structure "Widmanstattian" and refers to it as "being indicative

of weakness and lack of toughness. It is more commonly found in steel castings and in forgings which have been finished at too high a temperature.........the substitution of a fine grained uniform structure results in an improvement in the mechanical qualities."

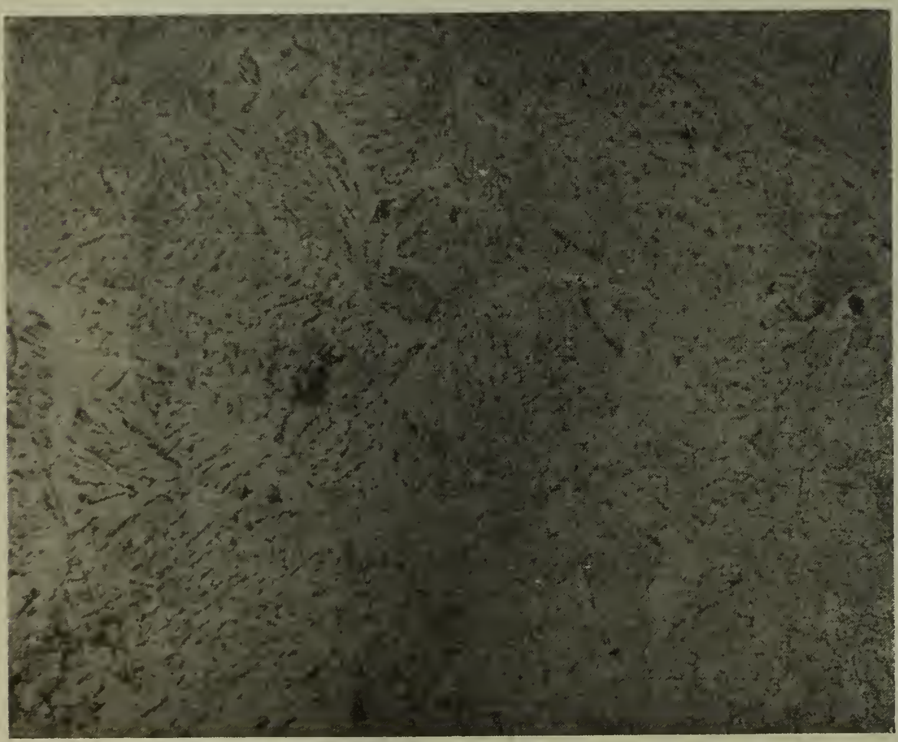

FIG. 9.—Junction—unenameled specimen.

Several strips from this sample were enameled in the usual manner following which portions of the weld were examined microscopically. It was found that the structure of the filler was essentially the same as that previously noted while the coarse structure of the plate as shown in figure 9 had been reduced to a fine one of the same general type as that originally existing in the plate, the banded structure being absent.

Figure 10 shows the junction between the filler and the plate indicating a reasonably even distribution of the pearlite among the ferrite grains.

Several observations of the same genreal type have been made both on experimental pieces, and on samples taken from units which had been processed commercially. We will take time to present but one additional case.

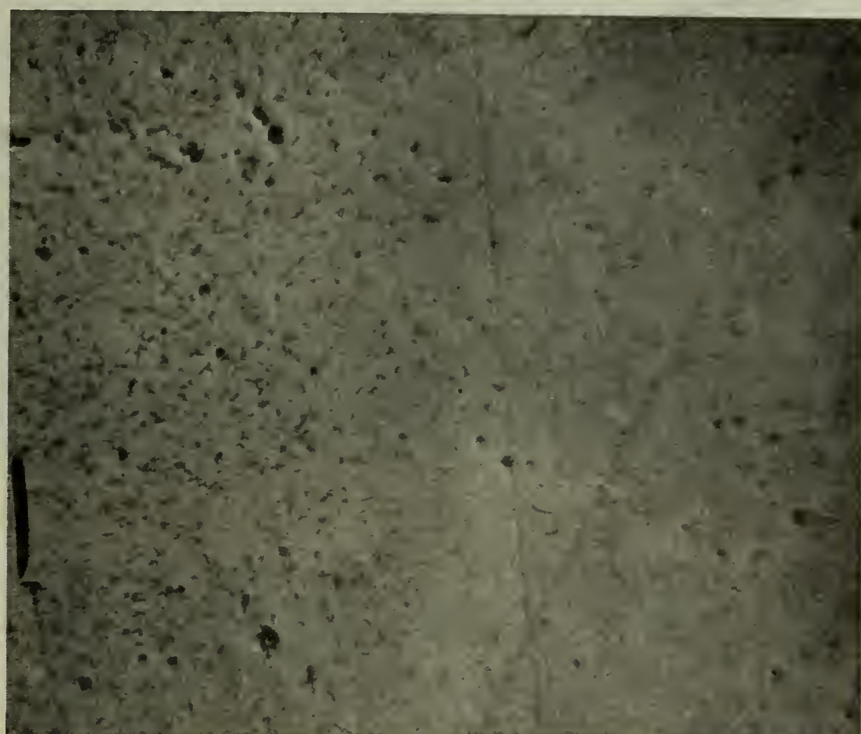

FIG. 10.—Junction—Enameled specimen—from same weld as figure 9.

Figure 11 shows the junction between the filler and plate in which the plate structure had taken the form of a very coarse grain. It is interesting to compare this structure with that given by S. W. Miller,[1] who discusses "Some Structures with Steel Fusion Welds," and shows a figure of an oxy-acetylene weld exhibiting the coarsening of grain of ordinary metal.

A specimen from the same weld was enameled and later examined microscopically. The results are shown in figure 12, in which the coarse structure of figure 11 has been reduced to a very fine structure with reasonably uniform distribution of pearlite.

[1] See figure 2, *Trans. Amer. Inst. Min. Eng.*, **1918**, 339.

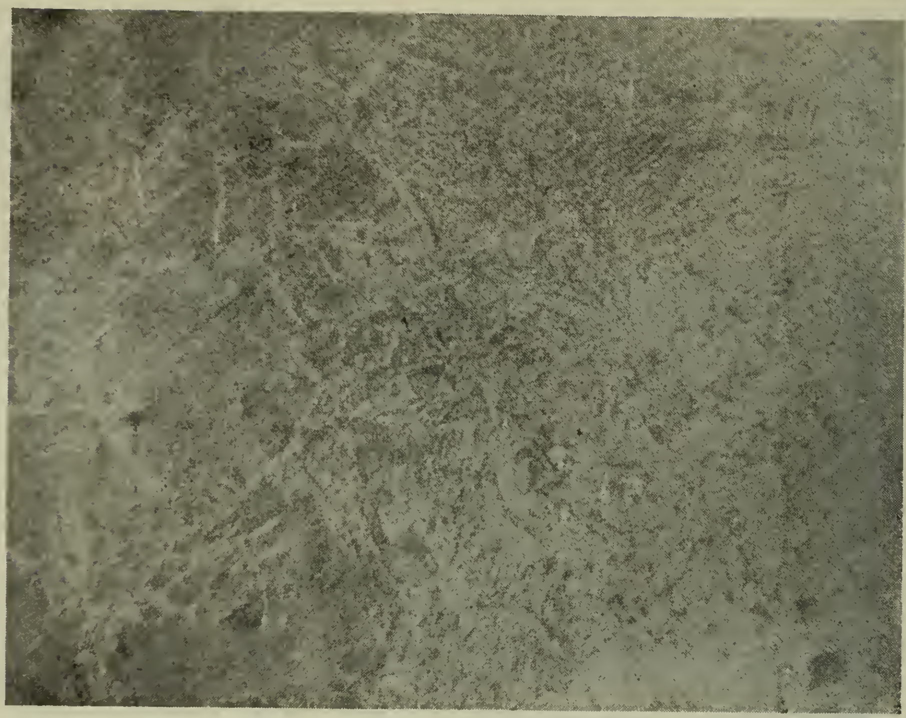

Fig. 11.—Junction—unenameled.

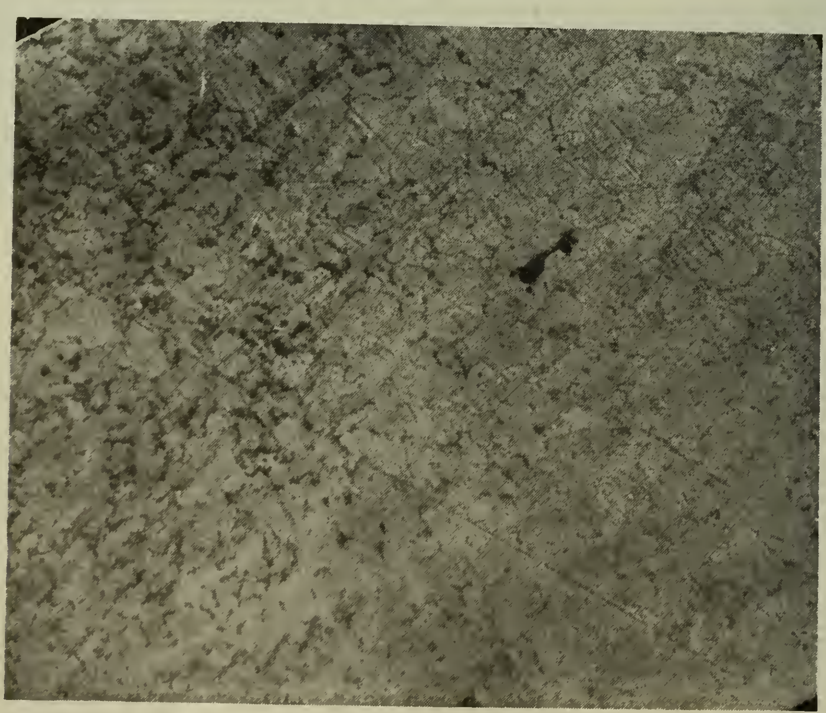

Fig. 12.—Junction—enameled from same weld as figure 11.

The above work indicates very definitely that the enameling operation furnishes very thorough annealing of the welds producing structures which indicate very desirable mechanical qualities as compared with those suggested by the unenameled samples and often considered as characteristic of oxy-acetylene welds.

This work will be followed by physical tests which should throw considerable light on the practical results of the changes noted herein.

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THE SEPARATION OF LIME FROM DOLOMITE[1]

By H. G. Schurecht

ABSTRACT

Calcination.—Magnesium carbonate in dolomite is decomposed by calcining for one hour at 800°C. Calcium carbonate is not completely decomposed until after calcination at 960°–1040°C for one hour.

Treatment with sulphuric acid.—By adding sufficient H_2SO_4 to milk of dolomite to react with the lime present, a bulky precipitate of $Mg(OH)_2$ is formed which may be partially separated from the finer $CaSO_4$ by screening through a 120 mesh sieve. The residue on the screen contains about 68.3 per cent MgO and represents over 50 per cent of the original CaMgO.

Flotation.—The best results by flotation were obtained by removing the fine material from the raw dolomite and then calcining at 920°C. Wood creosote flotation oil number 400 was found best suited for this separation. The concentrates removed by flotation, however, represent only 25 per cent of the dolomite originally treated.

Leaching and screening.—By a leaching and screening treatment it is possible to obtain a product containing about 80 per cent MgO. This is superior to Canadian magnesite in MgO content.

Elutriation.—By an elutriation treatment it is possible to obtain a residue containing over 85 per cent MgO and representing about 30 per cent of the original dolomite.

Introduction

In previous work[2] the writer found that it was difficult to produce fire brick from calcined mixtures of dolomite and hematite, which would withstand storage in the open air for periods of time longer than six months. During this period the free lime and lime compounds combine with the moisture or change in volume causing the brick to disintegrate. Finer grinding of the raw dolomite before calcination with hematite proved beneficial in many cases but did not entirely overcome the tendency to disintegrate. Calcining the raw dolomite and hematite mixtures at higher

[1] Received March 14, 1921. Published by permission of the Director, U. S. Bureau of Mines.

[2] This Journal, 4 (1921).

temperatures in some cases increased the tendency of the resultant material to disintegrate. Magnesite on the other hand, can be easily dead-burned and magnesite brick withstand storage in open air, remaining sound, for long periods of time. Magnesite brick are also more resistant to slagging action than dolomite brick and for this reason it has been claimed[1] that the life time of a magnesite bottom is three times that of a dolomite bottom.

Prior to the war, practically all the magnesite used by the steel industries came from Austria and was laid down on the American seaboard at from $15 to $18 per ton. During the war[2] the prices of domestic magnesite increased to $50, $75 and finally $100 per ton the chief source of this material being the State of Washington.

At the present time, caustic lump magnesite is quoted[3] at $35 to $40 per ton, carload lots, f.o.b. California. In the Chicago district it is quoted at $57.70 and at the Atlantic seaboard at $61 and $63. Dead-burned magnesite is quoted at $38 per ton at Chewelah, Washington and $58–$64 per ton at Chester, Penna.

Dolomite,[4] 1 and 2 man size, is quoted at $1.60–$1.65 per ton. 2–8 in dolomite is quoted at $1.55–$1.65 per ton f.o.b. Plymouth Meeting, Pa.

Since the price of one ton of dead-burned magnesite delivered to Pennsylvania points is at present equal to that of 37–39 tons of raw dolomite, the problem of concentrating the magnesia in dolomite by reducing the lime content, was considered worthy of investigation.

The work herein reported is therefore limited to a study of the separation of lime from dolomite. Various processes already patented were studied as well as other processes which were developed in the laboratory as the work progressed.

The Work of Previous Investigators

Closson[5] separated magnesia from dolomite by adding 8750 parts of magnesium chloride to 1250 parts of caustic dolomite.

[1] McDowell, Spotts, J., and Howe, R. M., "Magnesite Refractories," This Journal, 3, 189 (1920.)

[2] Bankson, R. A., "Glory Holes and Magnesite," *Eng. & Min. Jr.*, **111**, 49–52 (1921.)

[3] The Market Report, *Eng. & Min. Jr.*, **111**, 85 (1921).

[4] *Eng. & Min. Jr.*, *loc. cit.*

[5] This appears as footnote 1 on p. 560.

The lime in the dolomite combines with the nagnesium chloride forming soluble calcium chloride and a precipitate of magnesium hydroxide. The soluble calcium chloride is then removed by filter pressing leaving 1000 parts of magnesia in the press.

By the Pattinson method[2] magnesia is separated from dolomite by subjecting the same to a pressure of 5–6 atmospheres in the presence of carbonic acid. The solution is then heated with steam and the precipitate of magnesia dried.[3]

In another process[4] dolomite is calcined at 500–600°C at which temperature the carbon dioxide is driven from the magnesium carbonate, while the calcium carbonate remains in the undissociated form. The magnesia is then removed either by air or water separation.

By the addition of a small amount of sugar or molasses to milk of dolomite, the lime readily goes into solution while magnesium hydroxide remains as a precipitate. Scheibler[5] uses this reaction in the separation of lime from dolomite. He adds 10–15 per cent sugar or molasses solution to milk of dolomite. The solution of the lime by sugar takes place rapidly leaving magnesium hydroxide as a precipitate. The lime sugar solution is then separated by decantation or filtration. The sugar and lime are recovered by passing CO_2 through the solution thus forming CaCO and sugar.

Bradburn[6] uses a by-product in the manufacture of soda by the ammonia process to separate magnesia from dolomite. This by-product contains 60–90 parts NaCl and 120–180 parts NH_4Cl. The dolomite is so calcined to decompose both the calcium and magnesium carbonates. The calcined dolomite is then hydrated. The milk of dolomite is then mixed with the solution of sodium and ammonium chlorides. The liquor contains calcium chloride, magnesium chloride and sodium chloride with an excess of NH_4Cl.

[1] Scherer, R., *Der Magnesit*, A. Hastleben's Verlag, Wien und Leipzig, 84, (1908).

[2] *Der Magnesit, loc. cit.*, p. 134.

[3] This is substantially a literal translation but does not describe the process clearly.

[4] *Der Magnesit, loc. cit.*, p. 134.

[5] *Ibid.*, p. 135.

[6] Bradburn, J. A., "Process of Obtaining Magnesia," U. S. 1,156,662, Oct. 2, 1915.

The clear liquor is decanted and sufficient milk of dolomite is added to convert the $MgCl_2$ into $Mg(OH)_2$.

The $Mg(OH)_2$ from the milk of dolomite does not enter in the reaction but is collected with the precipitated $Mg(OH)_2$. The mixture is then passed through a settling tank and the heavy MgO is deposited near the inlet while the light $Mg(OH)_2$ together with the $CaCl_2$ is carried off in the overflow. The $Mg(OH)_2$ is then filtered and washed free from chlorides.

Another process[1] consists in crushing calcined dolomite to 8–40 mesh size and subjecting it to a leaching process with cold water which dissolves the lime leaving the magnesia as an insoluble residue. This process is continued until the residue contains not more than 3–10% lime.

A patent was issued to Mitchell[2] for obtaining magnesium oxide from dolomite by calcining at 950°F which decomposes the magnesium carbonate but not the calcium carbonate. The magnesium hydroxide formed on the addition of water is separated by running water or air (this process being practically the same as that described under reference No. 9).

Epsom salts[3] are made from dolomite by treating dolomite with sufficient H_2SO_4 to react with the calcium and magnesium present. The resultant magnesium sulphate solution is then filtered from the calcium precipitate.

Experimental Methods

The following methods are briefly outlined for the processes used for the separation of lime from dolomite in this work. In each case chemical analyses were made of the samples separated and the CaO and MgO contents expressed in terms of the oxides. This was also done when undecomposed $CaCO_3$ was present to make the results more comparable.

[1] "Refractory material and process for making same," U. S. 1,270,819, July 2, 1918.

[2] Mitchell, A. M., "Process for Obtaining Magnesium Oxide from Dolomite," U. S. 1,273,110, July 16, 1918.

[3] Newth, G. S., "A Text Book of Inorganic Chemistry," Longmans, Green & Co., New York, 1905, 575.

1. **Treatment with Sulphuric Acid.**—1000 Kilogram samples of dolomite were calcined at 1040°C and hydrated. Enough H_2SO_4 was added to react with the $Ca(OH)_2$ and the fine crystals of $CaSO_4$ thus formed were removed from the bulkier $Mg(OH)_2$ by screening.

2. **Separation by Flotation.**—1000 Kilogram samples of dolomite crushed to 8–20 mesh size were calcined at 760°, 840°, 920° and 1040°C and hydrated. The magnesium hydroxide was removed to some extent by flotation. This was possible because of the fact that $Mg(OH)_2$ is more colloidal (slimy) than the undecomposed calcium carbonate and certain forms of lime hydrate.

The same experiments were made on dolomite which had been screened through a 100 mesh sieve, previous to calcination. Wood creosote flotation oil number 400 of the Pensacola Tar & Turpentine Co. was found best suited for this separation and therefore was used.

3. **Separation by Leaching and Screening.**—1000 Kilogram samples of dolomite crushed to 8–20 mesh size were calcined at 840°, 920°, and 1040°C and hydrated. Different samples of each were then passed through the following mesh size screens: 4, 20, 65, 100 and 200. The materials passing through the screens were then leached with water for 4 days. The same experiments were made with dolomite which had been screened through a 100 mesh sieve previous to calcination.

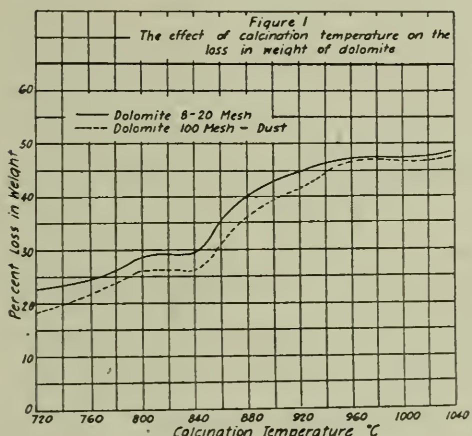
4. **Elutriation Tests.**—1000 Kilogram samples of dolomite crushed to 8–20 mesh size were calcined at 840°, 920°, and 1040°C and hydrated. Sieve analyses were made to separate the hydrated material into the following sizes: 20, 20–65, 65–100, and 100–200 mesh. The material which passed through 200 mesh was separated by elutriation according to the method described for the elutriation of clays.[1] The same experiments were made with dolomite which had been screened through a 100 mesh sieve previous to calcination.

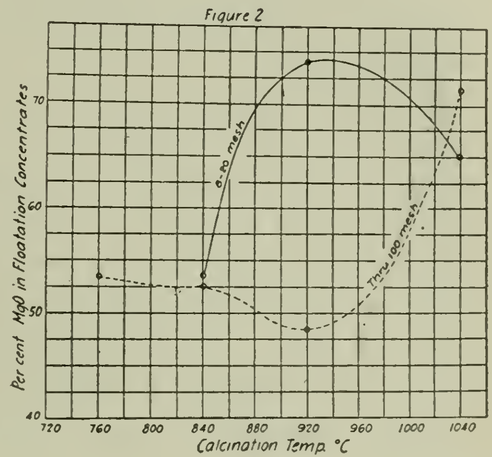
Results

The Effects of Calcination Temperatures on the Dissociation

[1] THIS JOURNAL, 3, 355–78 (1920).

of Dolomite.—Cedarville dolomite[1] crushed to 8–20 mesh was calcined for 1 hour at 720°, 760°, 800°, 840°, 880°, 920°, 960°, 1000° and 1040°C, respectively. The same was repeated with dolomite screened through a 100 mesh sieve. The losses in weight at these temperatures are shown in figure 1.





It is obvious that 8–20 mesh dolomite may be calcined more thoroughly than the 100 mesh size as shown by the greater loss in weight of the coarser sizes.

The magnesium carbonate is apparently decomposed by calcining at 800°C while the calcium carbonate is not completely decomposed until 960°–1040°C.

Treatment with Sulphuric Acid.—In treating the hydrated dolomite with sulphuric acid, sufficient acid was added to the milk of dolomite to react with the lime present. A bulky precipitate of $Mg(OH)_2$ is thus formed and the calcium sulphate is present as extremely fine needle-like crystals. Due to the difference in the structures of the $CaSO_4$ and $Mg(OH)_2$, the former may be removed largely by screening through a 120 mesh sieve. The residue remaining on the screen contains about 68.3% MgO and, in terms of $CaMgO_2$, represents over 50% of the dolomite originally used. By violent agitation and washing with water all of the colloidal

[1] The chemical analysis of Cedarville dolomite is as follows: CaO = 30.2 %, MgO = 21.8%, CO_2 = 46.8%, SiO_2 = 0.4%, Al_2O_3 = 0.5%, Fe_2O_3 = 0.5% and hydro. water = 0.1%.

$Mg(OH)_2$ may be forced through the sieve. Utilization of the calcium sulphate thus removed in the manufacture of plaster of paris or Estrich's plaster is a possibility, though not investigated at this time.

Separation by Flotation.—Figure 2 shows the results obtained in the separation of magnesium hydroxide from dolomite by flotation. The best results were obtained by calcining 8–20 mesh dolomite to 920 °C. Removing the fine material through a 100 mesh sieve before calcination seems necessary as shown in tests made on dolomite which had been screened through a 100 mesh sieve. For example, the concentrates from dolomite which had been crushed to 8–20 mesh size and calcined at 920 °C contained 74 per cent MgO, whereas that from dolomite screened thru a 100 mesh sieve and calcined at the same temperature contained only 48.5 per cent MgO. This is due largely to the fact that the fine undecomposed calcium carbonate is carried away with the froth.

When calcined at 1040 °C the concentrates obtained from the 8–20 mesh and 100 dust dolomite, were both comparatively high in MgO, containing over 65 per cent. This may be partly due to the leaching action of water on the caustic lime present.

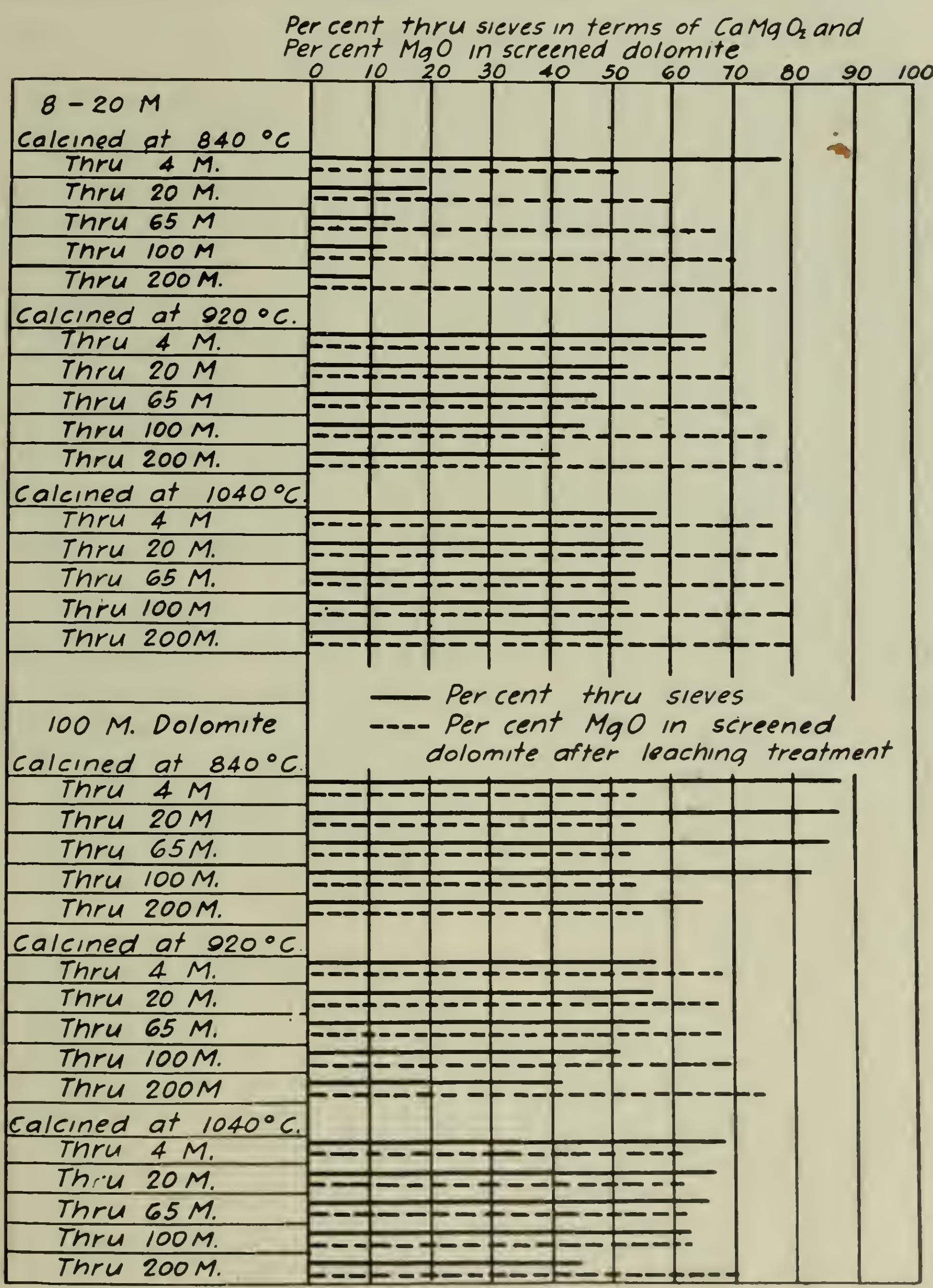
The concentrates removed by flotation, however, represent, in terms of $CaMgO_2$, only about 25 per cent of the original dolomite used. By the sulphuric acid and screening and leaching treatments, a 50 per cent recovery is obtained. If more than 25 per cent concentrate is forced over the flotation cell, it rapidly increases in lime content.

Separation by Leaching and Screening.—The solubility of $Ca(OH)_2$ is 0.185 gram per 100 grams of water (Seidell), whereas that for $Mg(OH)_2$ is 0.014 gram per liter (Riddell),[1] at room temperatures. By allowing water to run for a number of days over dolomite, calcined sufficiently high to decompose both the $MgCO_3$ and $CaCO_3$, a large per cent of the lime may be removed owing to its greater solubility in cold water and to its finer particles which are carried away mechanically.

[1] Duschak, L. H., "The Determination of Free Calcium Oxide in Caustic Burned Magnesium Oxide." *Bureau of Mines Reports of Invest.*, June, 1–2, 1920.

In this portion of the work therefore, the effect of size of grain and calcination temperature on the separation of lime from dolomite by leaching and screening were studied. Water at room

Figure 3



temperatures was allowed to run over 300-gram samples of calcined dolomite at the rate of 100 cc. per minute for 4 days. The undecomposed calcium carbonate was then further removed by screening.

The results are shown in figure 3. It is obvious that the best results are obtained by crushing dolomite to 8–20 mesh, calcining at 1040°C, and allowing water to flow over it for 3 to 4 days. For example, by crushing dolomite to 8–20 mesh size, calcining at 1040° hydrating with water, screening through a 100 mesh sieve and leaching for 3 to 4 days, a product is obtained containing about 80 per cent MgO with less than 3 per cent $SiO_2+Al_2O_3+Fe_2O_3$ This material represents, in terms of the oxides, about 50 per cent by weight of the dolomite originally used showing that practically all of the MgO is recovered from the dolomite by this method. Calcined Canadian magnesite contains 72.7% MgO and 6.7% $SiO_2+Al_2O_3+Fe_2O_3$.[1] Obviously by this process, a product richer in magnesia than Canadian magnesite may be produced. Screening the dolomite through a 100 or 200 mesh sieve after hydration is advantageous especially if undecomposed calcium carbonate is present as is shown in figure 3.

The results also show that it is advisable to remove material finer than 100 mesh before calcination. This is partly due to the fact that the finer undecomposed calcium compound passes through the screens in the subsequent screening thereby increasing the lime content in the material passing the screens. Also the fine dolomite dust is not as thoroughly decomposed as is the coarser material due to freer egress of the CO_2 through the voids in the coarse material. The percentage of undissociated dolomite is therefore higher in the fine material.

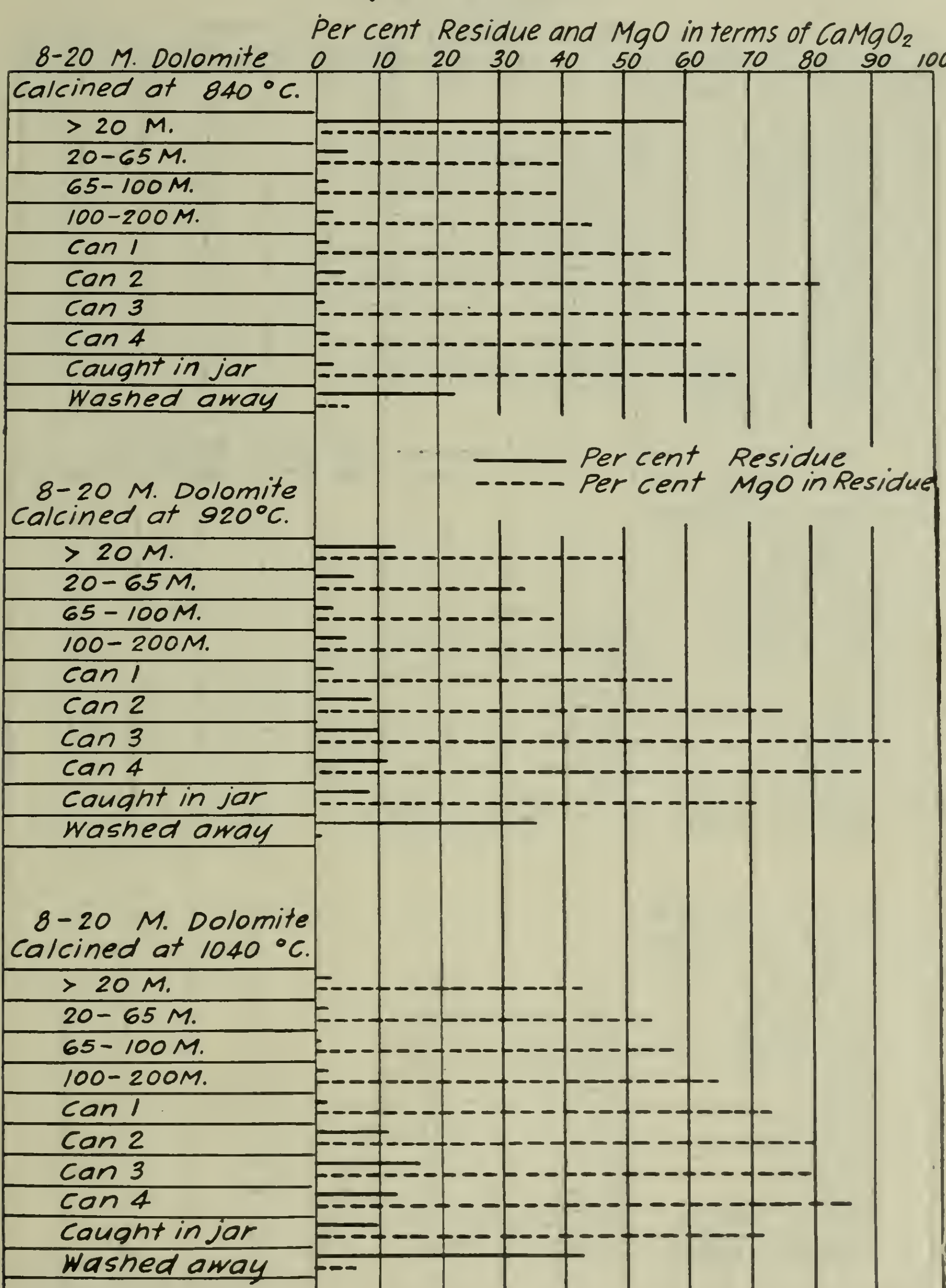
Elutriation Tests.—The results of elutriation tests on dolomite are shown in figures 4 and 5. In most cases the percentage MgO in the portions separated increases up to can 3 and then decreases in can 4 and in the overflow jar. As high as 44 per cent lime is washed away being largely dissolved in the water. The velocities of flow in the respective cans are as follows:

	Can. 1	Can 2	Can 3	Can 4	Per sec.,
Velocity......	0.347	0.180	0.059	0.0197	mm.

[1] Analysis made by A. Fieldner, U. S. Bureau of Mines, Pittsburgh, Pa.

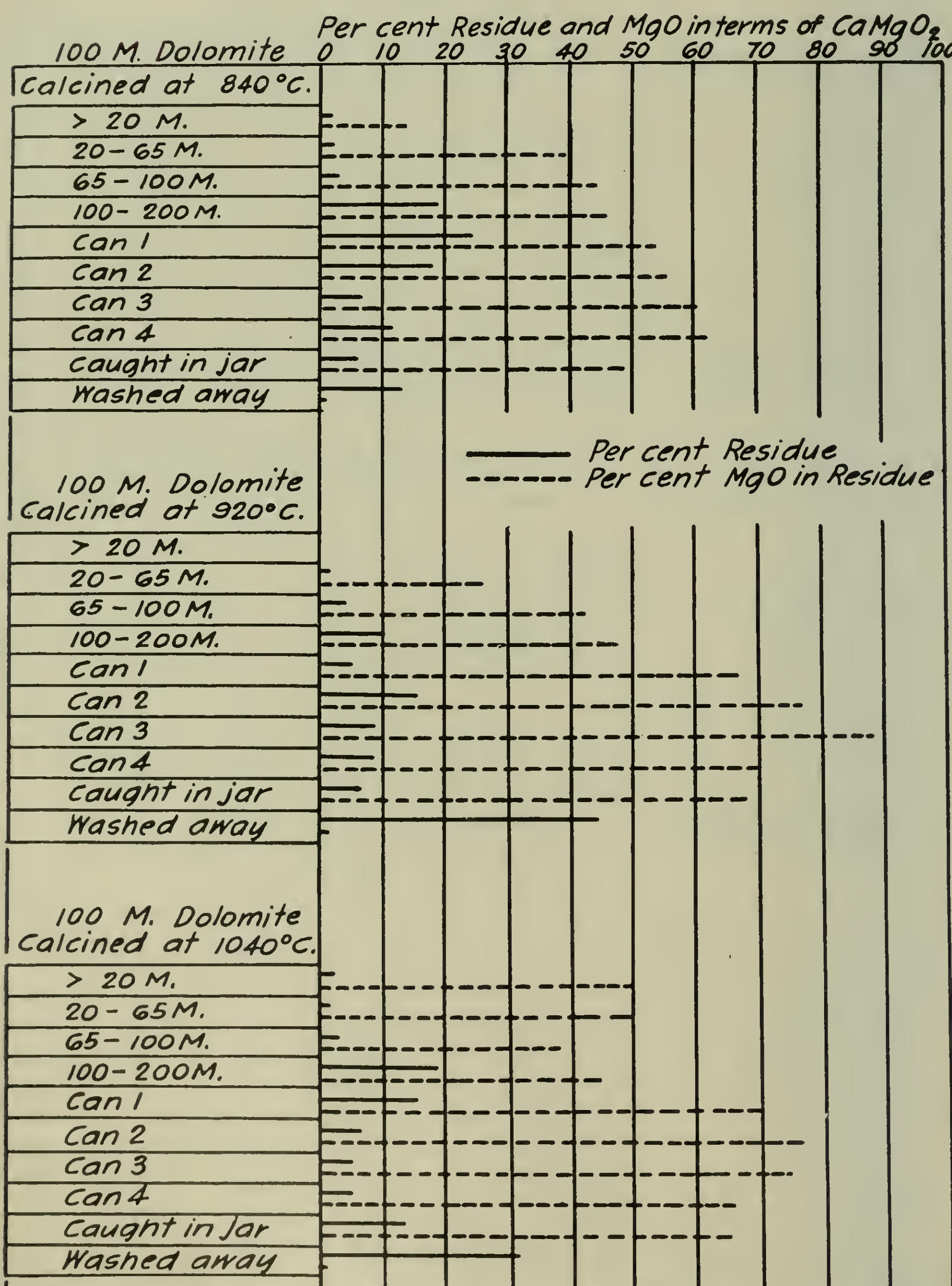
When 8–20 mesh dolomite was calcined at 920 °C and elutriated, the material deposited in can 3 contained 92% MgO. This however, only represents 9.5 per cent of the dolomite originally treated in terms of oxides or 21 per cent of the MgO originally

Figure 4



present in the dolomite. By combining the residues deposited in cans 2, 3 and 4, a product averaging 85.4 per cent MgO was obtained which represents 30 per cent of the dolomite originally used in terms of the oxides or 61.6 per cent of the MgO present in the

Figure 5



original dolomite sample. In other words, by using an elutriation system whereby the velocity of flow in vessel 1 is 0.347 mm. per sec. and in vessel 2 is 0.0197 mm. per sec., a product containing 85.4 per cent MgO is deposited in can 2 which represents 61.6 per cent of the MgO present in the dolomite originally treated.

Conclusions

The leaching and screening process gives the most satisfactory yields of MgO rich material.

If a high degree of purity is desired, combinations of the above treatments may be used, but for many purposes a product containing over 80 per cent MgO would probably be sufficient.

These processes have not yet been tried on a large scale and the results above are those obtained in the laboratory.

In conclusion the author wishes to acknowledge his indebtedness to Mr. R. T. Stull for many valuable suggestions in the work.

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PLASTIC MAGNESIA CEMENTS[1]

By P. H. Bates and Roy N. Young

ABSTRACT

Preparation of the Cement.—Crystalline magnesite from Washington was crushed to three sizes—to pass a No. 6 sieve but retained on a No. 10; between a No. 10 and a No. 30 and to pass a No. 60 sieve. These sizes were burned separately in an electric rotary kiln at 600°, 650°, 700°, 800°, and 900°C.

Tests of the Cement.—The cement was tested in three flooring mixes in which the MgO was 35.0, 42.5 or 50.0% by weight, and in three stucco mixes in which the MgO was 11, 22 or 33% by weight. Tensile and compressive strength specimens were broken at 24 hours, 7 and 28 days. The coefficient of expansion was determined at 48 hours, 4, 7, 28 and 90 days. Other properties determined were time of set, consistency, soundness, fineness and effect of density of the chloride solution used.

Results.—The property of the calcined cement is materially affected by the size of ore, temperature and duration of burning. The rate of reaction of MgO with chloride materially decreases with increased temperature of burning.

Decreasing the concentration of the magnesium chloride solution (down to 22° Bé) accelerates the set of freshly calcined magnesite and retards the set of magnesia which has become hydrated to a considerable extent through exposure. Exposure to moisture before using as well as increasing the consistency of the mixture lengthens the setting lime.

A composition which expands excessively and warps or buckles is not necessarily "unsound," but one which disintegrates within a comparatively short time may be considered as such. Used in this sense, "unsoundness" is believed to result from the presence of free magnesia which hydrates after the mixture has hardened, and not from the presence of lime. Therefore, soundness is not a property of the magnesia alone but depends upon the extent to which it reacts with the magnesium chloride, water, or carbon dioxide before hardening takes place and upon the amount of hydration which subsequently occurs. The steam or cold water tests are unsatisfactory as accelerated tests for soundness of magnesia mixtures.

Under the conditions of these tests, the best material with regard to setting time and strength was produced at a temperature of 800°C. However, the magnesia burned at 650°C and which gave comparatively very low strength when gaged with a 22° Bé solution of magnesium chloride, gave excellent strengths when gaged with more concentrated solutions. Materials tested with 22° Bé solution and giving satisfactory results would not necessarily

[1]Received April 15, 1921. Published by permission of the Director, U. S. Bureau of Standards.

be satisfactory with a higher or lower concentration. It seems that general specifications should also include limits corresponding with tests in which higher and lower concentrations are used.

No relation was found between the volume change and any other property of the magnesia. Tests of any particular mixture are no indication of the behavior of the same magnesia in other mixtures. However, the laboratory tests indicate that the leaner mixtures undergo less change in volume than the richer ones. Furthermore, a number of strict comparisons between laboratory and field tests indicate that the laboratory tests of volume changes as made are no index to the behavior of the material under actual service.

The lean mortar mixture proved to be the most suitable of any used for testing magnesia, and in this case the tensile strength furnished as much, if not more, information than the compressive strength.

Introduction

The data presented and discussed herewith represent the results obtained from a preliminary investigation dealing with the production of plastic (or so-called caustic) magnesia from domestic magnesites and the testing of the product to determine some of its properties as a cementing medium when mixed with a solution of magnesium chloride and certain inert fillers, as finely ground sand, asbestos, wood flour, and coloring.

Previous to the late war practically all of the magnesia used as a cementing agent for resilient floors came into this country from Greece. Usually it had been calcined before its arrival and in the majority of these cases the calcination had been made in Holland for the purpose of obtaining carbonic acid. The cutting off of this supply necessitated the more active development of domestic sources of similar material. These had been noted to exist in California and had been worked for some time for a number of purposes other than the production of plastics for flooring or stucco. Like the Grecian ore or a similar ore from Venezuela the California ore is said to be amorphous, (and microscopically it does appear so), and is in striking contrast to the magnesite from the State of Washington, which is very crystalline.

While a very satisfactory ore was therefore at hand, there was but little known in regard to its proper preparation and calcining as a plastic cement, or of the properties which the latter should have to assure satisfactory results in its application. An investigation was therefore undertaken to determine these factors

using the amorphous ore. Later it was thought desirable to include the crystalline variety on account of the very large deposits in Washington and also because it was learned that some of this variety from Austria had been going into the plastic trade abroad.

The complete outline of the investigation includes the burning of various sized ores from different localities at different temperatures. From the ground calcine the usual tensile, compressive and transverse strength test pieces will be made, as well as tests to determine the constancy of volume of different flooring and stucco mixtures. There will also be made a number of test panels of flooring and stucco, which will be subjected to actual service conditions.

This paper, however, covers only the results of some preliminary work in which one variety of magnesite alone was investigated and in which the prime object was to determine how the ore crushed to different sizes would be affected by burning at different temperatures. It would in a measure determine the sizes and temperatures to be used in the remainder of the work. On account of its nature only part of the tests outlined above were carried out. The results though not conclusive are so suggestive of different lines of future work, that it was thought they would be of much interest to those engaged in the investigation of oxy-chloride cements.

Description and Properties of Materials

Magnesia.—The magnesite used throughout these tests was from Stevens County, Washington, and all of the same shipment except as shown in table I. It was crushed to three different sizes. The first contained the particles which passed a No. 6 sieve and were retained on a No. 10 sieve, the second was between the No. 10 and No. 30 sieves, and the third was sufficiently fine to pass a No. 60 sieve. Each size was burned at the temperatures 600°, 650°, 700°, 800° and 900°C making 15 burns in all. The burning was done in a small electric resistance rotary kiln. During the operation of the kiln, the variation from the desired temperature was seldom more than 10° as found by temperature readings taken every 10 minutes. The time required for the material to pass

through the kiln was approximately one hour. The material which was crushed to the finest size progressed somewhat slower than the coarse size, and at the higher temperatures had a slight tendency to stick to the kiln lining. After burning the material was ground and placed in tightly covered metal containers until used.

The results of the chemical and physical tests of the raw and finished materials are given in tables I and II, respectively. Attention is called to the range of CO_2 content, and the variation in the amounts of this constituent with the fineness of ore and the burning temperature. It may be well to explain that these analyses were made after the burned material was ground, which

TABLE I—RESULTS OF CHEMICAL ANALYSES OF THE RAW AND FINISHED MATERIALS

				RAW MATERIALS				
Lot		SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	CO_2	Ig. loss
1		1.03	.80	.52	1.95	46.22		49.81
2		2.12	.72	.66	.88	45.18		49.96
				BURNED MATERIALS				
Burn	Lot							
xB-1*	2						28.00	30.50
B-2*	2						7.05	17.50
B-3*	1						5.60	9.92
xC-1	2						4.35	7.00
C-2	2						3.50	6.90
C-3	2						3.80	5.67
xD-1	2						2.85	4.00
D-2	2						2.65	3.40
D-3	2						1.85	2.55
xE-1	2						1.30	2.42
E-2	2						1.75	2.40
E-3	2						.85	1.75
xF-1	2						.20	.75
F-2	2						.15	.70
F-3	2	4.49	1.36	1.68	1.57	90.40	.28	.50

xB burns made at 600°   *1 Material sized between No. 6 & No. 10 sieves
C " " " 650°   2 " " " No. 10 & No. 30 "
D " " " 700°   3 " all through No. 60 "
E " " " 800°
F " " " 900°

TABLE II—RESULTS OF PHYSICAL TESTS ON THE FINISHED BURNED MATERIALS

Cement	Fineness Per cent retained on No. 100 sieve	No. 200 sieve	(Specific Gravity)	Loose Wt. per Cu. Ft. (Lbs.)
B-1	0.2	12.8	3.05	60.7
B-2	0.4	9.6	3.06	46.8
B-3	0.6	12.6	3.13	45.5
C-1	0.6	10.8	3.22	42.8
C-2	1.4	13.1	3.26	45.6
C-3	0.2	9.7	3.05	43.5
D-1	1.4	12.6	3.05	50.2
D-2	2.4	12.6	3.13	52.8
D-3	0.8	10.1	3.22	51.7
E-1	1.8	12.8	3.34	52.3
E-2	2.2	14.1	3.38	52.8
E-3	1.4	14.3	3.35	51.4
F-1	0.9	12.3	3.40	50.9
F-2	1.9	13.6	3.43	53.2
F-3	0.5	10.3	3.44	55.5

will, to some extent, account for the amount of water present. In this connection, it is interesting to note the relative activity of the different burns towards moisture as shown by the following tests.

Five grams of the finished material from each burn made on the coarsely crushed magnesite were spread out on a cover glass and placed in moist air which was free from carbon dioxide. At certain periods the samples were dried and weighed, and the increase in weight was converted to percentage increase in combined water. These data are given in table III. It may be seen that the

TABLE III—PERCENTAGE INCREASE IN WEIGHT DUE TO HYDRATION OF MAGNESIA FROM VARIOUS BURNS UPON EXPOSURE TO MOIST ATMOSPHERE

Burn	Duration of exposure				
1 Day	2 Days	7 Days	14 Days	28 Days	
B-1	8.68	10.14	16.88	17.08	
C-1	13.37	19.43	24.95	26.22	
D-1	10.50	14.55	25.55	27.55	
E-1	1.44	1.84	11.76	21.56	21.96
F-1	0.97	2.24	10.13	15.30	16.81

activity of the magnesia toward moisture decreased as the calcining temperature increased. Although the amount of hydration of burn B-1 was less than that of the others, due to the large amount of undecomposed $MgCO_3$, yet if calculated on the basis of caustic magnesia content it was higher.

Magnesium Chloride.—The results of analysis of the magnesium chloride solution were as follows:

SiO_2	0.0007%		
R_2O_3	.0024		
SO_3	.0085		
CaO	.085		
MgO	8.80	≈	20.86% $MgCl_2$
Cl_2	15.50	≈	20.83% $MgCl_2$
Specific gravity	1.184		

Flint.—This material is that known as "potters' flint." The lot which was used in these tests had a fineness of 99 per cent through a No. 100 sieve and 89.6 per cent through a No. 200 sieve.

Asbestos.—The asbestos used in the flooring mixtures was what is known commercially as grade "C."

Details of Tests of Cement Mixtures

Mixtures

Cement from each burn was used in 6 different mixtures of the following compositions.

	Compositions (percentage by weight)			
Marked	MgO	Flint	Sand	Asbestos
AF	50.0	30.0		20.0
BF	42.5	34.5		23.0
CF	35.0	39.0		26.0
AM	33		67	
BM	22	11	67	
CM	11	22	67	

The three containing asbestos will be referred to as flooring (F) mixtures and the others as mortar (M) mixtures.

Mixing

The dry materials were thoroughly mixed before gaging with the magnesium chloride solution and only a sufficient amount

was used at one time for molding 3 to 6 briquettes or 1 to 3 of the larger test specimens. The mixing was done in accordance with the method described in the U. S.[1] Government Specification for Portland Cement. Exceptions to this occurred in a number of cases in which it was impossible to give the full time to the mixing operation on account of the very quick setting property of the material. However, by very rapid work, thorough mixing was accomplished.

Consistency

A standard consistency for the flooring mixtures was adopted, which appeared to be about the same as that used in the testing

TABLE IV—RATIOS OF MAGNESIUM CHLORIDE TO CEMENT AND CONSISTENCIES USED IN THE VARIOUS TESTS

	Flooring Mixtures						Mortar Mixtures					
	** Ratio $\frac{MgCl_2}{MgO}$			*Consistency (% by weight)			Ratio $\frac{MgCl_2}{MgO}$			Consistency (% by weight)		
Burn	A	B	C	A	B	C	A	B	C	A	B	C
B-1	.256	.275	.334	62	58.7	58.7	.119	.150	.262	19	16	14
B-2	.297	.330	.395	72	68	67	.156	.197	.318	25	21	17
B-3	.297	.330	.395	72	68	67	.162	.197	.318	26	21	17
C-1	.297	.330	.395	72	68	67	.168	.206	.337	27	22	18
C-2	.297	.330	.395	72	68	67	.168	.206	.337	27	22	18
C-3	.297	.330	.395	72	68	67	.159	.197	.318	25.5	21	17
D-1	.297	.330	.395	72	68	67	.168	.201	.318	27	21.5	17
D-2	.297	.330	.395	72	68	67	.168	.201	.318	27	21.5	17
D-3	.297	.330	.395	72	68	67	.156	.197	.318	25	21	17
E-1	.297	.330	.395	72	68	67	.144	.178	.300	23	19	16
E-2	.297	.330	.395	72	68	67	.144	.178	.300	23	19	16
E-3	.297	.330	.395	72	68	67	.144	.178	.300	23	19	16
F-1	.297	.330	.395	72	68	67	.125	.169	.300	20	18	16
F-2	.297	.330	.395	72	68	67	.125	.169	.281	20	18	15
F-3	.297	.330	.395	72	68	67	.119	.159	.281	19	17	15

*Per cent (22° Bé $MgCl_2$) of weight of dry mix.

**Ratio $\frac{MgCl_2}{MgO}$ = ratio per cent anhydrous $MgCl_2$ to per cent calcined magnesite and hence is *not* a molecular ratio. In a formula such as as $MgCl_2 \cdot 5MgO$ the ratio of per cent $MgCl_2$ to per cent MgO is .473.

of neat Portland cement. By an examination of table IV, it may be seen that the same percentage of solution was used for all the flooring mixes of the same proportions with the exception of those which contained magnesia from burn B-1. It is not claimed that this percentage of solution produced the same consistency throughout, but in consideration of the difference in the properties of the various mixes, especially setting time and smoothness, it is believed that this method was more satisfactory than attempting to change the percentage of solution slightly in each case as might have been done had the judgment of the operator been relied upon entirely in duplicating consistencies.

In the mortar tests it was necessary to follow the latter procedure and here again it was difficult to decide just what was the proper consistency for the reasons mentioned above. It was impracticable to use any measuring device on account of the rapid stiffening of the mixture which occurred in many cases. No doubt some method such as is used in determining consistency or "flowability" of cement or concrete may be applied to compositions of these types, assuming that quick setting or very early stiffening would preclude the use of such material in practice.

Time of Setting

The time of setting was determined by the use of Gilmore needles. No difficulty was encountered in applying this method to the flooring mixtures, but the mortars required a slight change in the manner of observing the set. As the condition of the latter mixtures approached the initial set the penetration of the needle became very ununiform, for if the tests were made at different places on the same specimen the needle made no impression in some places and penetrated appreciably in others. This difficulty was overcome as follows: It was found that after the needle ceased to penetrate there was usually a short time during which the material yielded under the pressure of the needle. It appeared that this yielding was not affected by the coarse sand particles as was the penetration of the needle. It was therefore considered that a mortar had attained its set when the material ceased to yield under application of the needle, and in this way perfectly satisfactory results were obtained.

TABLE V—SETTING TIME

	Flooring Mixtures						Mortar Mixtures					
	Initial			Final			Initial			Final		
	*A	*B	*C	A	B	C	A	B	C	A	B	C
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
B-1	35	35	1 5	2 40	2 55	3 15	3	5	15	5	15	25
B-2	10	15	20	40	1 30	1 40	2	2	5	3	5	20
B-3	40	40	1 10	2 15	2 25	1 45	5	5	15	10	15	35
C-1	45	55	40	1 40	1 55	2 30	10	10	35	30	50	1 10
C-2	20	25	40	1 25	1 5	2 20	5	10	15	10	20	45
C-3	1 10	1 30	1 30	3 10	2 45	3 10	30	1	1 10	1	1 20	1 45
D-1	1 5	1 10	1 20	2 40	3 30	3 25	15	25	40	50	1 5	1 35
D-2	2	1 55	2 10	2 35	3 30	3 30	30	45	55	1 20	1 25	1 50
D-3	3 35	3 30	3 50	5 45	5 50	6 40	1 50	2 10	2 20	2 40	3	3 20
E-1	4	4 55	5	6 35	7 20	8 15	3	3 40	4 25	4	4 55	6 10
E-2	4 20	4 45	4 55	7	7 45	8 15	3	4 5	4 20	5 30	5 20	6 5
E-3	4 50	4 25	5 15	7 50	6 35	9 25	3 55	4 35	5 15	5 40	6 40	7 10
F-1	9 20	9 10	9 35	(a)	(a)	22 15	3	3 45	4 55	4 25	5 30	8 45
F-2	9 30	9 50	(b)	21 50	22 55	24 15	3 25	3 25	4 10	4 40	6 20	8 40
F-3	9 35	9 45	(b)	23 50	22 45	29 30	3 15	3 55	4 35	4 40	6 35	9

(a) Less than 22 hrs.
(b) More than 10 hrs.

*A, B, C refer to composition as given under "Mixtures" on page 575.

As may be seen by an examination of table V, a very distinct relation exists between the temperature at which the magnesite was calcined and the setting time, that is, increases in the burning temperature resulted in slower setting. Also there is a tendency for the setting time to become slower with a decrease in the percentage of magnesia contained in the mixture, which may be due to a change in both the ratio of magnesium chloride to magnesia and the ratio of the amount of solution to magnesia. Again, there was a tendency for increased fineness of the raw material to result in slower setting, which no doubt may be explained from the fact that at any particular temperature the finer raw material is more readily calcined than the coarser material.

Soundness

The pats used in the setting time tests were employed in comparing different methods for making soundness tests. One pat from each mix was placed in the air of the laboratory after being stored in the moist closet for 24 hours, a second was placed in water and a third was subjected to steam at atmospheric pressure for 5 hours.

None of the air pats up to 28 days showed signs of unsoundness with the exception of those made from mixes B-1AM,[1] C-1AM, C-1BM, C-2AM, and C-2BM which developed radial cracks. Cracks were also observed in the strength specimens made from these mixes appearing sooner in the 2″ x 4″ cylinders than in the briquettes. All the water pats of this series were softened a great deal within 7 days. Some of them were barely brittle with little swelling while others were very soft, swelled or badly cracked. There was very little difference in results produced in the flooring pats as all could be broken easily with the fingers. The mortar pats showed a greater variation in the effects of the water storage but little of definite value was obtained from these tests. Differences occurred more noticeably among the mixes of different proportions rather than among those containing cements burned at different temperatures. The mixes containing the smallest amounts of cement seemed to be less affected than the others, but this was not true in all cases.

[1] In this notation "B" refers to temperature of burning, "1" to sizing (see table I), "A" to mix (see composition page 575), and "M" signifies mortar.

TABLE VI—RESULTS OF STRENGTH TESTS

	Tensile Strength—Lbs. per Sq. In.																	
	Flooring Mixtures, Age									Mortar Mixtures, Age								
	24 hrs.			7 days			28 days			24 hrs.			7 days			28 days		
Burn	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
B-1	287	248	250	283	323	283	528	535	305	247	168	220	270	225	228	385	332	280
B-2	263	260	218	323	293	297	257	215	233	270	212	178	212	185	173	185	130	75
B-3	458	586	545	498	605	653	675	705	760	323	318	238	435	367	347	550	437	322
C-1	337	367	332	360	352	353	287	337	398	358	378	280	283	245	297	193	185	287
C-2	327	338	320	417	372	328	320	380	315	487	402	265	232	208	238	207	248	363
C-3	375	348	367	493	435	440	533	613	628	203	140	298	370	543	407	490	640	703
D-1	543	543	622	620	605	640	515	653	697	362	457	352	530	598	395	452	460	492
D-2	660	575	615	650	630	650	768	723	808	383	380	398	330	558	510	578	572	528
D-3	620	690	590	708	663	645	708	667	762	642	513	382	1,097	893	755	1,113	947	935
E-1	545	515	437	558	658	612	733	748	788	448	442	342	873	692	712	832	825	978
E-2	598	553	470	590	565	760	735	658	878	522	358	295	748	717	637	668	847	797
E-3	573	548	493	862	845	672	882	848	695	445	358	313	757	583	613	758	763	763
F-1	*595	*545	*390	933	862	592	818	867	695	270	237	155	818	718	535	773	642	682
F-2	*557	*420	*300	752	632	482	742	793	692	277	215	110	613	580	470	620	653	603
F-3	*250	*248	*223	373	412	407	650	592	642	212	117	*153	630	518	253	885	793	525

TABLE VI—(Continued)

Compressive Strength—Lbs. per Sq. In..

B-1	490	565	485	590	560	585	2,080	2,025	1,495	1,315	875	855	1,535	1,070	1,125	1,700	1,540	1,910
B-2	620	530	415	540	494	475	480	485	525	1,190	958	692	976	767	692	1,025	845	690
B-3	1,425	1,220	1,240	1,820	1,590	1,745	2,380	2,475	2,335	2,170	1,755	1,625	2,645	2,160	1,750	2,490	2,030	2,140
C-1	665	587	835	515	490	745	420	580	805	1,905	1,735	1,350	1,950	1,570	1,340	1,745	1,535	1,595
C-2	695	655	545	681	674	652	510	750	895	1,565	1,428	1,070	1,075	1,350	1,150	1,340	1,545	1,510
C-3	1,060	865	905	1,085	930	1,060	2,085	1,590	1,775	1,545	1,425	1,535	2,190	1,620	2,005	2,445	2,650	2,785
D-1	1,685	1,835	1,800	2,030	2,230	2,160	2,090	2,785	2,755	1,975	2,650	2,150	2,070	3,075	2,475	2,500	3,320	3,110
D-2	2,765	2,510	2,200	2,905	2,675	2,620	3,510	3,265	3,265	2,630	2,535	3,140	2,870	...	3,645	3,270	...	3,990
D-3	3,260	3,160	2,830	3,900	3,300	3,055	4,710	4,270	4,125	6,480	5,180	3,920	7,910	6,790	5,210	9,540	7,730	7,010
E-1	2,865	2,720	2,140	3,975	3,990	3,525	4,420	5,150	4,920	5,210	4,375	3,045	8,040	6,840	4,870	9,300	7,660	6,400
E-2	1,980	2,070	2,370	3,250	2,775	3,685	3,795	3,315	4,340	5,500	3,170	2,840	7,850	7,020	4,780	8,550	7,930	5,880
E-3	3,170	2,855	2,135	5,165	4,430	4,040	6,820	6,250	5,925	5,980	3,980	2,840	8,810	6,610	4,735	8,770	7,815	5,915
F-1	*2,585	*2,105	*1,525	4,500	3,770	3,240	5,610	5,050	5,010	2,510	2,060	730	7,730	5,585	4,020	8,375	5,060	4,490
F-2	*2,100	*1,585	*1,020	3,925	3,475	2,870	5,780	4,195	4,720	2,450	1,795	600	6,950	4,985	3,695	7,250	5,680	4,990
F-3	*1,095	*835	*650	3,815	2,980	2,500	6,690	6,690	5,510	2,040	950	*942	6,045	4,770	2,815	6,270	6,140	5,680

*Tested at 48 hours on account of slow setting.

The steam test gave results similar to those obtained by storing the pats in water, and the same general remarks as to effects of water storage may be repeated here. The steam test, however, was considerably more severe.

Strength Determination

Strength test specimens were made in both tension and compression. The Standard briquette and method of molding for testing Portland cement were used in the tension tests and 2″ x 4″ cylinders in the compression tests. The specimens were not placed

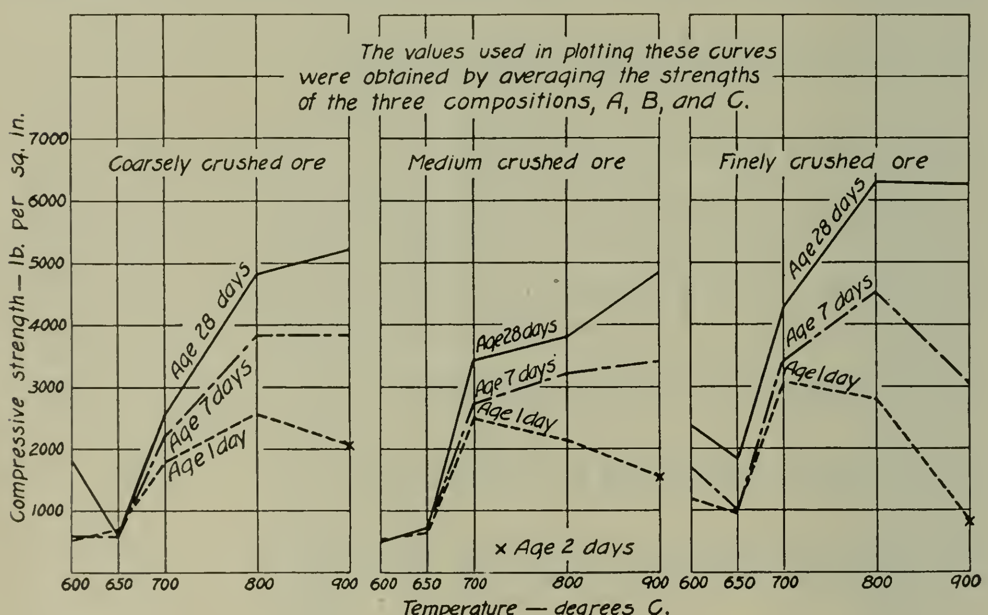


FIG. 1.—Compressive strength of flooring mixtures as affected by size of ore and burning temperature.

in a damp closet after molding but were protected from loss of moisture to the atmosphere by covering tightly with glass plates. At the end of 24 hours, they were removed from the molds and stored in the laboratory freely exposed to the atmosphere until tested.

The results of the strength tests are given in table VI, each being an average of 3 tests. The effects of the calcining temperature and size of ore on the strength of the flooring and mortar mixtures are shown in figures 1 and 2, respectively. In order to avoid the use of the large number of curves necessary to show the tests in detail the results obtained from averaging the strength

of the three mixes of different proportions (A, B, and C) containing magnesia from the same burn were plotted.

These data show that there is an optimum temperature required for burning the magnesite, under the conditions used in these tests, to develop the best strength at the early period. Apparently the magnesia burned at 600 and 650°C was under-burned, though the question arises as to whether or not the magnesia was more active and required more chloride than actually

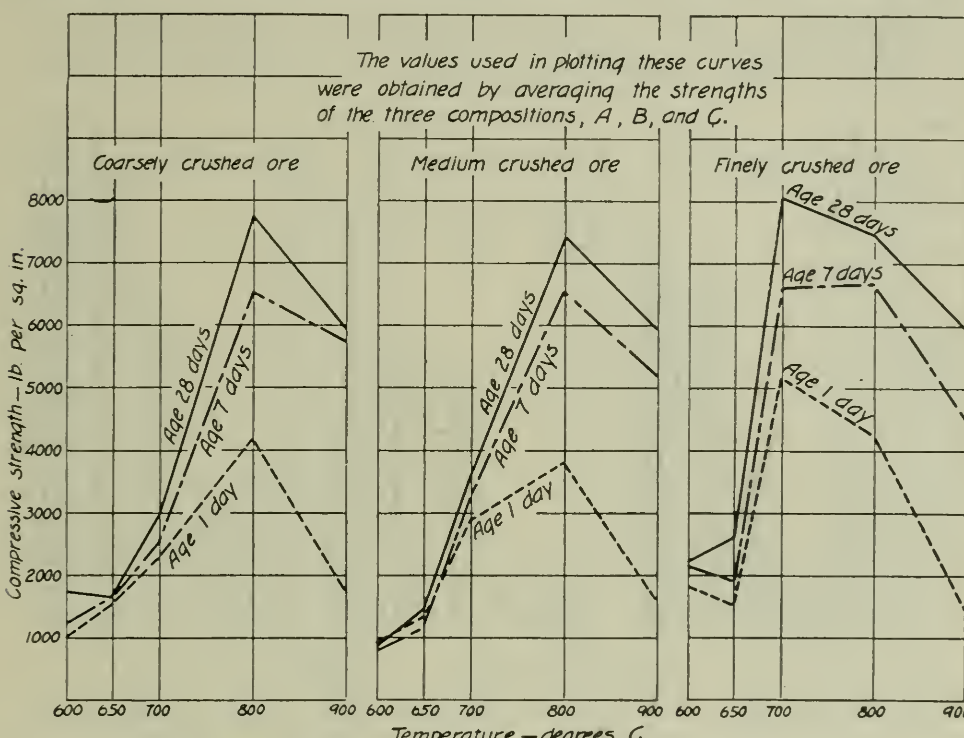


FIG. 2.—Compressive strength of mortar mixtures as affected by size of ore and burning temperature.

used. The disintegration of the test piece made from such burned material at late periods of storage and the results given in table VIII would indicate that under-burning was not the reason for the low strength of the low burned magnesia, but rather the use of too small an amount of chloride. Over-burning is apparent in the results obtained from the test pieces made from the finely crushed magnesia burned at 800 and 900°C. But this is manifested only by low early strength, as at the late periods the strength furnishes few data to assist at arriving at a proper burning temperature.

Comparing the strengths developed by the calcining of the coarse, medium, and fine ground ore at any one temperature it is clearly evident from the 24-hour strength alone that the fine ground material is the more readily burned. Hence after low burning it is the more active, while after calcination at the higher temperatures it is the more inactive.

Figures 3 and 4 are for the purpose of comparing the 28-day strengths obtained in the use of different proportions of magnesia and aggregate. There is very little difference in the strengths of the three flooring compositions, and even among the mortars,

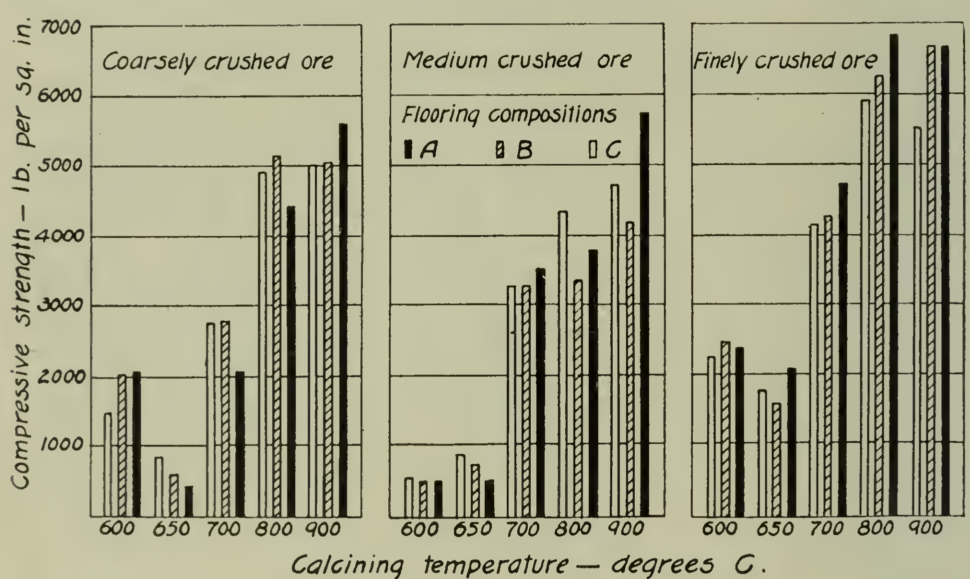


FIG. 3.—Comparison of the compressive strengths of the various flooring compositions at the age of 28 days.

in which the percentage of magnesia varies from 11 to 33 per cent, there is generally comparatively little difference in most cases. The maximum increase in strength resulting from a 200 per cent increase in magnesia content was only 87 per cent. This difference of strength between the lean and rich mixtures occurred with the cements from the burns at the higher temperatures which were presumably the less active. These facts again suggest that low strength was not an inherent quality of the low burned magnesite, as in that case an increase in the proportion of magnesite within limits should have resulted in higher strengths. In other words,

the low strength may have been due to the increased activity of the magnesia, advantage of which was lost by the use of the same amount of chloride as used in the more inactive product.

Another interesting relation derived from the strength tests is shown in figure 5. It was noticed that the ratio of tensile strength to compressive strength varied a great deal in the tests on the

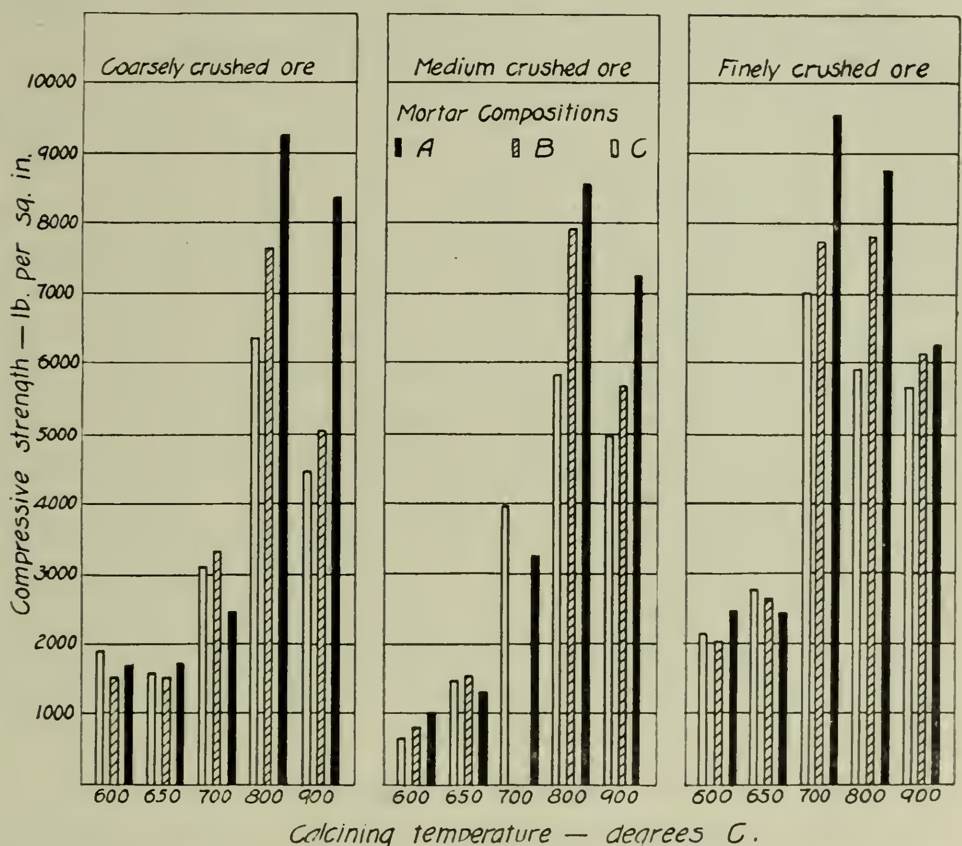


FIG. 4.—Comparison of the compressive strengths of the various mortar compositions at the age of 28 days.

flooring mixtures. By plotting the compressive strength against the ratio of tensile to compressive strength, it was found that all points fell in the close vicinity of a smooth curve, regardless of the magnesia or the proportions used. It may be seen that the tensile strength varies from approximately 10 per cent to 80 per cent of the compressive strength and that the ratio increases as the strength decreases. All results of the 28-day strength tests of the various flooring mixtures were used. The point to be emphasized is that

the relation between tensile and compressive strength is not a straight line relation in this type of mixtures, as is often assumed, but that the ratio of tensile to compressive strength varies considerably with the strength.

The variation in this ratio is a great deal less among the mortar tests, being from about 8 per cent to 24 per cent. Furthermore, the relation between tensile and compressive strengths, although somewhat similar to the above, is much less obvious.

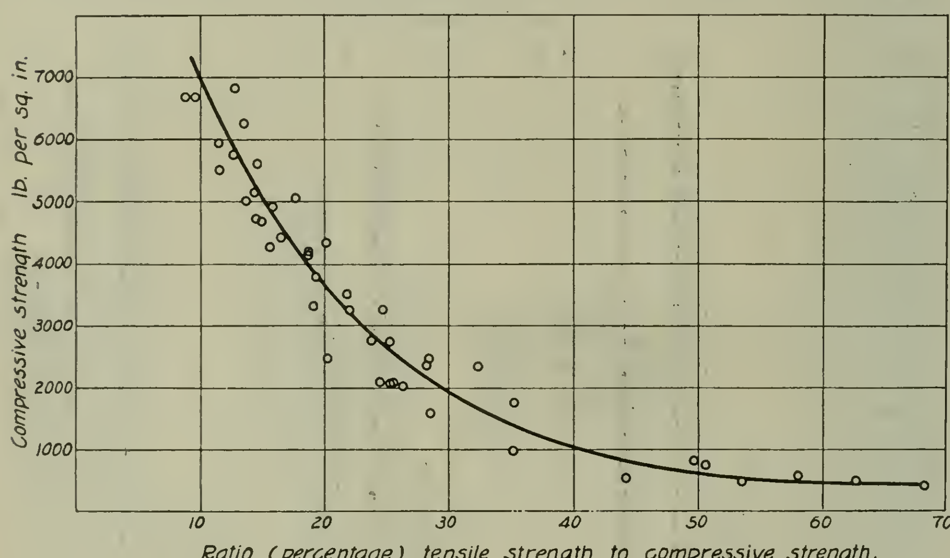


FIG. 5.—Relation of tensile to compressive strength of the flooring mixtures at 28 days.

Change in Volume

The linear changes of specimens 1 inch by 1 inch by 14 inches long were measured by means of a Berry strain gauge. These bars were molded in the same manner as the briquettes, but the upper surface was left exposed to the air during the first 24 hours. They were then removed from the molds and stored in the air of the laboratory in a horizontal position supported at two points one-fourth the length from the ends with all sides exposed.

Warping to a greater or lesser degree occurred in nearly all bars, usually beginning before the 28-day period. In nearly every case, the warping has been in the vertical plane with respect to the position in which it was molded and stored, with a bowing up of

the centers of the bars. It was thought that the manner in which they were stored might influence the warping, so one bar of some of the sets was stored with the side molded last facing down. These bars warped with the centers bowing down which showed that the warping was influenced to little extent by the storage position. The reason for this warping or unequal change in lengths of the top and bottom of the specimen is not evident. Without doubt errors were introduced in the results of these measurements on account of this, but since the change in volume was usually comparatively large in cases of bad warping, very accurate results were unnecessary.

The results of these tests expressed in thousands of a per cent are given in table VII. The initial readings in a large number of cases were made at the time of final set but these are not shown. To make the table consistent throughout all calculations were based on the 24-hour reading. It may be seen that the behaviors of the various mixtures appear very erratic and very little relation seems to exist between change in volume and any of the other properties of the mixes or conditions of tests. This was somewhat disappointing in view of the fact that a greater knowledge of the causes and of means for preventing excessive changes in volume was most desired. At least a test by which materials undesirable in this respect may be excluded is essential before magnesia compositions can be classed as a reliable building material. No very general conclusion can be drawn from the data. They indicate only certain trends—as the rich mixes expanding more than the lean ones the test pieces for the high burned magnesia expanding more than that from the low burned, and the more general constancy of the medium burned product.

Miscellaneous Tests

As previously mentioned, specimens from a number of mixes containing magnesia calcined below 700° showed signs of disintegration within a comparatively short time. The only plausible explanation of this seemed to be that there was an unusual amount of highly active magnesia present owing to the conditions of calcining and that the amount of magnesium chloride was insufficient to complete the reaction in the formation of magnesium

TABLE VII—RESULTS OF CHANGE IN VOLUME TESTS

Flooring Mixtures

Linear Changes in Thousandths of a Per Cent—between the Ages of 24 Hrs. and

	48 hrs.			4 days			7 days			28 days			3 mos.		
Burn	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
B-1	+319	—36	—13	+3	—88	—24	+191	—84	—41	+14	—92	—22	+28	+50	+282
B-2	—25	—26	—25	—25	—38	—46	—27	—46	—67	—(a)	—(a)	—(a)	—(a)	—(a)	—(a)
B-3	+24	+18	—3	+3	+17	—9	—25	—6	—1	—143	—72	0	—133	—51	+4
C-1	+45	+22	+6	+57	+27	—1	+86	+45	+8	+253	+118	+49	+487	+221	+109
C-2	+27	+8	+4	+93	+51	+29	+200	+105	+52	+217	+104	+112	+557	+292	+170
C-3	+14	+17	+13	+9	+11	+15	+22	+4	+25	+10	+18	+26	—33	—26	+26
D-1	+18	+15	+26	+40	+20	+12	+32	—6	+5	+27	+21	+15	—75	—122	—14
D-2	+48	—104	+48	+76	+61	+47	+77	+75	+48	+70	+64	+46	+4	—11	+49
D-3	+98	+118	+114	+142	+129	+137	+111	+107	+127	+82	+90	+126	+123	+111	+130
E-1	+174	+114	+140	+228	+155	+193	+218	+154	+187	+225	+153	+190	+209	+140	+172
E-2	+411	+176	—103	+483	+239	—57	+494	+247	—47	+489	+244	—52	+481	+235	—59
E-3	+153	+135	+78	+227	+202	+126	+211	+191	+130	+224	+199	+132	+227	+200	+130
F-1	+161	+167	+150	+347	+373	+360	+421	+504	+558	+406	+492	+564	+395	+483	+548
F-2	+180	+167	+128	+437	+428	+286	+(a)	+(a)	+488	+(a)	+(a)	+(a)	+(a)	+(a)	+(a)
F-3	+87	+71	+41	+45	+201	+140	+327	+464	+378	+360	+551	+507	+347	+513	+489

TABLE VII—(Continued)

Mortar Mixtures

B-1	—11	+5	—10	—9	+16	—14	—52	—16	—45	+53	—75	+17	+17	—68	+30
B-2	+77	+27	—11	+77	+49	—16	+432	+72	—21	+(a)	+199	—254	+(a)	+118	+357
B-3	+15	+19	+14	+11	+22	+23	—8	+7	+11	—22	+34	—15	—8	+294	—17
C-1	+9	+73	+5	+232	+163	+7	+576	+325	+17	+(a)	+(a)	+63	+(a)	+(a)	+138
C-2	+79	+71	+4	+408	+390	+26	+(a)	+(a)	—33	+(a)	+(a)	+77	+(a)	+(a)	+243
C-3	...	+20	+12	...	+43	+12	...	+95	+8	...	+139	+1	...	+463	+12
D-1	+3	+1	+7	+38	+30	+16	+73	+49	+9	+131	+137	+11	+(a)	+391	—20
D-2	+4	+12	+11	+39	+34	+18	+66	+49	+16	+131	+98	+27	+(a)	+303	+19
D-3	—8	+9	+30	—28	+7	+37	—31	—10	+31	—9	—7	+22	+54	+24	+37
E-1	+11	+29	+79	—3	+30	+100	+5	+27	+105	+22	+36	+103	+104	+73	+99
E-2	+15	+59	+101	0	+53	+132	+9	+58	+138	+23	+70	+141	+95	+100	+134
E-3	+41	+78	+61	+35	+84	+84	+48	+92	+85	+64	+98	+86	+162	+134	+85
F-1	+197	+178	+141	+284	+235	+220	+253	+268	+340	+347	+269	+349	+337	+244	+338
F-2	+190	+176	—141	+254	+274	—38	+312	+315	+110	+367	+319	+118	+359	+300	+71
F-3	+208	+135	+5	+353	+322	+71	+384	+401	+123	+434	+401	+161	+410	+396	+152

+(a) Expansion beyond limits of instrument.
—(a) Contraction " " " "

oxychloride. As a consequence the remaining active magnesia slowly hydrated with the accompanying increase in volume and disintegration of the test specimen. In accordance with this reasoning, magnesite cement mixtures containing an insufficient amount of magnesium chloride might disintegrate in time, depending upon conditions such as amount of excess active magnesia present, moisture conditions, type of aggregate and the proportion of magnesia to aggregate and to chloride. Also, the rate at which such hydration takes place would depend largely upon the extent to which the magnesite was burned.

For the purpose of obtaining further information in this direction, the mixture which disintegrated to the greatest extent was duplicated and gauged with solutions of higher concentrations. The test specimens which were gaged with the same strengt solution (22°Bé.) as was previously used failed to behave as expected in that no excessive expansion or disintegration occurred within the same period, although there was a retrogression in strength with age. This would indicate that the original magnesia had undergone some change during storage. No doubt, owing to its activeness toward moisture, partial hydration had taken place, making the ratio of magnesium chloride to active magnesia higher in the later tests. However very marked increases in strength resulted from the use of the higher gravity magnesium chloride solutions, and this prompted the following series of tests.

Magnesite crushed to the fine size and calcined at 650° was used in the various compositions previously described and each of these was gaged with several solutions of different gravities.

The results of the strength tests are given in the first part of table VIII. It may be seen that by means of more concentrated solutions the compressive strength of each of these mixes was increased approximately from 300 to 600 per cent over that resulting from the use of the 22°Bé. solution. It seems therefore, that very much greater economy in the use of magnesite cement may be possible, that is, by the use of somewhat more concentrated solutions, a specified strength may be attained with considerably smaller proportions of magnesia. Furthermore, maximum strength does not result from any definite ratio between the magnesium

TABLE VIII—STRENGTH OF COMPOSITIONS AS AFFECTED BY CONCENTRATION OF SOLUTION AND CONSISTENCY

Composition	Marked	% Sol.	Ratio $MgCl_2$ / MgO	Sol[1], °Bé.	Strength (lbs. per sq. in.) Tensile 1 day	Tensile 7 days	Tensile 28 days	Compressive 1 day	Compressive 7 days	Compressive 28 days
AF	4–1	72	.290	22	375	493	533	1060	1085	2085
	4–2	72	.333	25	592	657	760	1235	1605	2775
	4–6	72	.468	34	902	965	907	6325	7305	7950
BF	4–3	68	.322	22	348	435	613	865	930	1590
	4–7	68	.520	34	1008	932	958	4840	5395	8060
CF	4–4	67	.385	22	367	440	628	905	1060	1775
	4–5	67	.500	28	758	742	790	3560	3760	4475
	4–8	67	.622	34	638	883	907	3500	4575	5980
AM	4–9	27	.169	22	203	370	490	1545	2190	2445
	4–12	27	.188	25	205	437	470	2115	3495	4285
	4–15	27	.239	31	543	985	880	7570	8820	9580
	4–17	27	.266	34	700	713	238	7405	8780	*8460
BM	4–10	22	.201	22	140	543	640	1425	1620	2650
	4–13	22	.261	28	415	780	415	5290	7080	6180
	4–18	22	.325	34	793	1173	1042	9410	8910	10950
CM	4–11	18	.329	22	298	407	703	1535	2005	2785
	4–14	18	.427	28	510	607	878	5315	6210	7120
	4–16	18	.478	31	477	540	770	5240	6000	6600
	4–19	18	.532	34	542	615	570	5175	5190	8800
CF	5–5	56.9	.327	22	433	535	628	945	1245	2340
	5–6	76.6	.440	22	455	483	617	975	1075	2535
	5–7	87.0	.500	22	370	445	605	800	1034	2105
	5–8	108.3	.622	22	283	347	528	620	854	1795
CM	5–1	15.2	.278	22	237	427	547	1690	2070	3045
	5–2	20.5	.375	22	275	397	625	1700	2170	3890
	5–3	23.3	.427	22	298	377	552	1800	2090	3900
	5–4	26.1	.478	22	258	348	547	1705	2020	3485

*Spalled badly before failing.

chloride and magnesia. This statement is conclusive from the above data, together with the results of tests given in the second part of table VIII. In the latter series the ratio of magnesium chloride to magnesia was varied in each mixture by changing the percentage of solution rather than by changing the strength of solution. Under these conditions the strength was not increased by an increase in the above ratio as in the former series, which shows that the consistency (and perhaps the ratio of solution to magnesia) is an important factor.

There are so many interesting and vital facts that can be brought out from the data in this table that it seems well to call particular attention to them. Thus the relation between the amounts of magnesia in the different mixes should be recalled,—the AF mix contains 50 per cent magnesia, BF 42.5 per cent and CF 35 per cent. However note that the latter when gaged with 28° Bé. solution gives as good tensile strength as the AF mix when gauged with 25°Bé. solution and far better compressive strength. In the mortar the AM mix contains 33 per cent magnesia, the BM mix 22 per cent and the CN mix 11 per cent. Here again it is evident that the latter mix with a chloride solution of greater concentration (28°Bé.) than commonly used produces practically as good tensile and compressive strength, especially at late periods, as the rich AM mix with a solution of either high or low concentration. However too sweeping deductions can not be made from such comparison of the mixes, as a close study of the data shows that each mix requires a study of the amount and concentration of the chloride used to produce the best strength. If it were a matter alone of chloride-oxide ratio, then the different flooring mixes in which such ratios as .333 and .322 or .500 and .520, and the mortar mixes in which ratios as .188 and .201 or .266 and .261 or .325 and .329 were used should give somewhat comparable results, but such is not the case. This is due almost undoubtedly to the fact that a differently proportioned mix of the same dry constituents was used. Hence as stated above the problem is not only one of consistency (amount of solution used) or chloride-oxide ratio but also the proper proportioning of the dry mix.

The striking feature of the data however is the fact that with such a very active magnesia as that used in this part of the investigation it is not possible to develop its qualities by the use of a wet consistency (or high percentage) of 22° Bé. solution. In the mortar mixes, 4–14 is comparable with 5–3, in that they are identical dry mixes, but the former was gauged with 18 per cent of 28°Bé. solution and the latter with 23.3 per cent of 22°Bé. solution, producing in both cases the same chloride-oxide ratio. But the use of the higher gravity solution produced by far the better strength. The same relation exists between the dry mixes of 4–16 and 5–4 and when the consistency of the two was changed, though the chloride-oxide ratio was maintained the same by the use of solutions of different gravity, better results were produced by the use of the more concentrated solution. Similar relations exist in the flooring mixes and hence similar comparisons can be made between mixes 4–5 and 5–7, or 4–8 and 5–8 and again it will be noted that the increased strength has been produced by the greater concentration of the solution. Or the matter may be stated in another way by saying that a larger amount of a relatively weak solution (22°Bé.) will not give with any one mix as high strength as a less amount of a strong solution.

Before leaving the study of these data it would be well to call particular attention to some of the very high strengths that have been obtained, especially with the very lean mixes, as for instance the flooring mix CF (758 and 638 lbs. per sq. in. in tension and 3560 and 3500 lbs. in compression at the end of 24 hours) when either the 28° or the 34° Bé. solution, respectively, was used. The flooring mix 4–7 containing 7.5 per cent more magnesia developed greater strength, but the strength of the 4–8 mix is more than that required for practically all purposes and the more economical. The mortar mixes containing but 11 per cent magnesia also developed very high strength with the more concentrated solutions, these ranging from 477 to 542 lbs. per sq. in. in tension at 24 hours and 570 to 878 lbs. at the end of 28 days; and in compression ranging from 5175 to 5315 lbs. per sq. in. at 24 hours and 6600 to 8800 lbs. at the end of 28 days. The highest values of any mix, either flooring or mortar, were 1173 lbs. per sq. in. in tension at the

end of 7 days for the mortar mix containing 22% magnesia, gaged with 34° Bé. solutions, and 10950 lbs. per sq. in. in compression at the end of 28 days for the same mix similarly gaged.

The manner in which setting time was affected is shown in table IX. In practically all cases the time of setting of a mixture was lengthened by an increase in the concentration of the solution.

TABLE IX—RESULTS OF SETTING TIME TESTS

Composition	Marked	Per cent solution	Ratio $\frac{MgCl_2}{MgO}$	solution °Bé[1].	Initial hr.	Initial min.	Final hr.	Final min.
AF	4–1	72	.290	22		20	1	50
	4–2	72	.333	25		25	1	50
	4–6	72	.468	34	1	25	2	40
BF	4–3	68	.322	22		30	2	50
	4–7	68	.520	34	1	25	2	50
CF	4–4	67	.385	22		30	2	45
	4–5	67	.500	28		45	1	60
	4–8	67	.622	34	1	45	3	30
AM	4–9	27	.169	22		22		10
	4–12	27	.188	25		5		10
	4–15	27	.239	31		10		35
	4–17	27	.266	34		20	1	45
BM	4–10	22	.201	22		4		15
	4–13	22	.261	28		10		25
	4–18	22	.325	34		35	1	40
CM	4–11	18	.329	22		10		30
	4–14	18	.427	28		20	1	
	4–16	18	.478	31		40	1	10
	4–19	18	.532	34	1	15	2	45
CF	5–5	56.9	.327	22		20	2	20
	5–6	76.6	.440	22		45	2	55
	5–7	87.0	.500	22	1	25	4	20
	5–8	108.3	.622	22	2	10	5	10
CM	5–1	15.2	.278	22		10		20
	5–2	20.5	.375	22		15	1	15
	5–3	23.3	.427	22		25	1	45
	5–4	26.1	.478	22		35	1	50

This is contradictory to the results obtained by some investigators. It was thought possible that the difference was due to the use of fresh low burned magnesite in one case and aged or higher burned magnesite in the other. Accordingly tests were made on magnesia from the F-3 burn and on two commercial compositions. The results of the tests on the high burned magnesia were similar to the above but even more pronounced, whereas the commercial mixtures set somewhat more quickly as the concentration of the solution was increased. Other tests of this nature lead to the conclusion that the apparently conflicting results were probably normal, which may be explained by the fact that sufficient exposure of magnesia to allow considerable hydration to take place will reverse the effects of increasing the concentration of the solution as compared with the effects on freshly calcined material.

Another point of importance is that higher concentrations of the solutions resulted in greater resistance to the action of water or steam on the set material. This was true without exception. The pats of all mixes gaged with a 22°Bé. solution became soft in the steam test but marked improvements were observed with each increase in the concentration of the solution. In fact the mixes containing the smallest proportion of magnesia and gaged with the 34° Bé[1]. solution appeared to be little affected by the steam treatment. It is therefore probable that greater resistance of stucco to the weather may be accomplished in this way.

However, before the use of strong solutions can be judiciously recommended, more comprehensive and conclusive data pertaining to the effects on volume changes is necessary. The results of expansion tests on the mixes of series 4 up to the 28-day period show that during this time the change in volume is influenced considerably, in some instances increased and in others decreased. The concentrated solutions caused the flooring mixtures to expand during the first 48 hours, but at the 28-day period the volume was approximately the same as the original, while those gaged with the 22°Bé. solution showed only a slight tendency toward expansion at the earlier periods and considerable contraction at 28 days. In contrast with the above, increased concentrations of the solution caused very great contraction of the richest mortar mixtures during the first 24 hours.

Another dissimilar behavior of this same magnesia occurred in the tests in which only the amount of solution was varied (series 5). In this instance only the flooring mixtures were affected to any considerable extent. The driest flooring mixture contracted 0.2 per cent in 28 days and as the percentage of solution (or the ratio of chloride to oxide) was increased, the contraction decreased until finally the highest percentage of solution resulted in an expansion of approximately 0.05 per cent. This further demonstrates the fact that a satisfactory explanation of the cause of changes in volume of such compositions is far from simple. There is no doubt that an explanation would involve a number of factors, some of which are dependent on others for their effectiveness in producing changes in volume. It would seem to follow, therefore, that such material as produced and used in practice, with the added variables necessarily introduced, presents a still more difficult problem in the matter of developing methods for avoiding the excessive changes in volume which persistently occur from time to time. Fortunately this does not seem to be the case. Limited tests indicate that in most of the stuccos and floorings the stresses developed due to a tendency toward a change in volume in the direction which might cause large cracks or buckling are usually sufficiently resisted by the high strength of the material itself, by its strong bonding power, and by the reinforcement, such as the fibrous aggregate, metal, or the material acting as the base. It may be that only the mixtures showing a very decided change in volume in the laboratory tests as made would give trouble in practice, providing, of course, that the material were properly placed. If this is true, then the problem is much less complicated than the laboratory tests might lead one to believe.

DESIGN OF A FURNACE FOR ANNEALING OPTICAL GLASS[1]

By Donald E. Sharp

ABSTRACT

Design of a natural-gas furnace for annealing optical glass.—Most of the furnaces built for annealing regular glassware are unsuitable for optical glass due to irregularity and inequality of temperatures. *Working drawings* are given for a successful *optical glass annealing furnace* operated by *natural gas*. The design is novel in the placing of the flues and burners in such a manner as to supply the heat and remove it in a symmetrical manner, thus obtaining uniformity of temperature.

In the course of the manufacture of optical glass in this country during the early days of the war, little was known of the design and construction of the furnaces which had been employed for this work abroad, and it was consequently necessary to rely on the experience of glass furnace builders for designs. Suitable designs for melting furnaces presented little difficulty to the few contractors whose services were available, but the annealing furnaces built were in some cases quite unsuitable for the careful treatment necessary in the proper annealing of optical glass. There were, to be sure, many lehrs and ovens already in successful operation in the glass factories of the country, but the heat treatment necessary for the successful annealing of bottles and thin articles of glass was found to be a much simpler process than the manufacture of large glass slabs and prisms of optical glass, which were sufficiently free from strain to enable their use in optical instruments of precision. Although the annealing temperatures of the glasses, and the proper cooling rates, had been determined, it was in many cases a hopeless task to attempt to hold the proper temperature for the length of time required, or to cool at the correct rate with the furnaces which were available.

The furnaces which were first used by the author in the early days of the war, were of the oven or kiln type, and were designed

[1] Received March 7, 1921.

and built by a contractor who was experienced in the manufacture of such furnaces for the bottle trade. The annealing chamber proper was approximately 4 ft. wide by 6 ft. long, the arched crown being about 18″ from the floor of the chamber and having a spring of about four inches. These furnaces would undoubtedly have been perfectly satisfactory for annealing bottles or tableware, but were entirely unsuccessful in annealing slabs of optical glass. The chief causes of their failure were combustion faults arising from poor burner and combustion chamber design. The temperature distribution was decidedly poor, and the free cooling rate so great that considerable fuel was necessary to maintain the furnace at the annealing temperature.

The fuel available was natural gas of 1120 b. t. u. per cubic foot supplied at four ounces pressure, but this fuel, though an excellent one, required a great quantity of air for perfect combustion. The burners used were eight in number, four on each side. Each burner consisted of a $1^1/_2$″ pipe extending through the side wall to the crown of the furnace and fitted on the outside with the ordinary commercial bunsen type of air-gas mixer. The jet opening was poorly proportioned to the gas pressure, the size of pipe, and the natural draft of the furnace, and the result was a yellow flame, quite prone to "strike back," and heating a more or less local area. No trouble with the burners was encountered while the door of the furnace was open and the furnace being filled with glass, but it was frequently found that soon after closing the door the oxygen in the chamber had been entirely consumed, and the flame extinguished because the mixers were not functioning properly.

The draft flues were in the conventional position, in the back wall of the furnace. The back was consequently always hotter than the front of the chamber, and the effect of this hotter portion combined with the effect of the local hot areas from the individual burners was to cause inequalities in temperature amounting to from 50° to 100°C.

The rapid free cooling rate of the furnace was due to the use of only eight inches of red brick as an insulating medium. The outer walls of the furnace and the crown were so hot when the

furnace was in operation that they could not be touched. The expense of fuel used to supply heat lost by radiation was consequently considerable.

In the absence of any better designs or any precedent by which to be guided, the author was prompted to take this work in hand, and as a result produced a rather unique design which not only overcame all of the faults of the furnace mentioned, but was found to require much less attention from the furnace operator. The worst of the faults were removed simultaneously by altering the construction and type of the burners, their position, and the position of the flues.

The burners used in the new design were of the perforated tube type; the size of jet and diameter of the burner holes which gave the best results being determined by trial. These dimensions and the general construction are shown in figure 1. It was found desirable to have many small holes rather than a few large ones in order to prevent a tendency to "strike back" when operat-

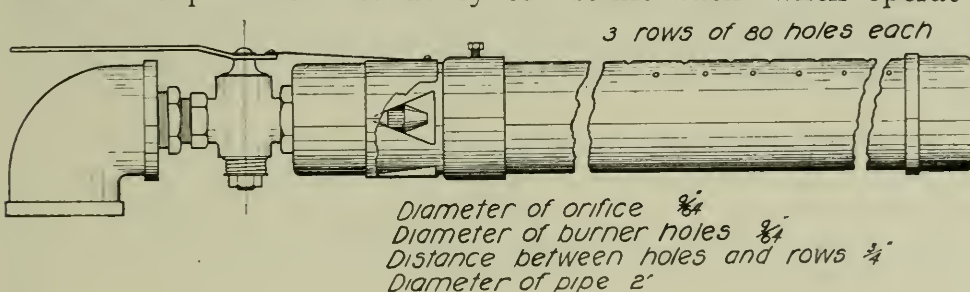


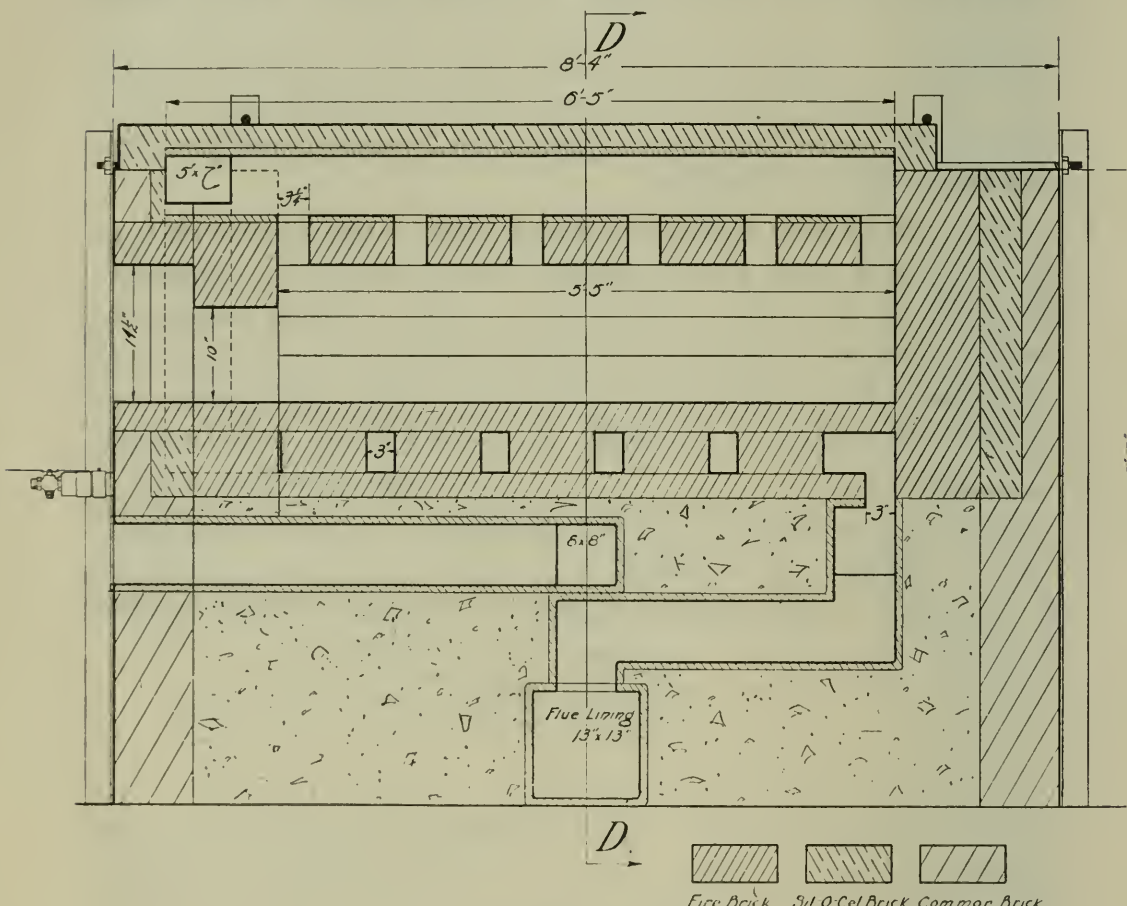
FIG. 1.

ing at a low temperature. The total area of the holes was made sufficiently great so that there was no back pressure or chance for a smaller volume of gas-air mixture to issue through the holes than the volume required by the dimensions of the mixer jet.

The system of flues, which may be understood readily by referring to the figures, is in the opinion of the author an original one. The auxiliary air ducts below the burner pipe insure a large enough supply of air to give perfect combustion even when the furnace is running at a high temperature, and prevent the flame from rising above the pipe as frequently happens when a large volume of gas is fed to a bunsen burner in a closed chamber.

The hot products of combustion pass up and over the breast wall to the furnace chamber and thence through holes in the top of the crown. It should be noted that the heat is thus supplied to the furnace in an entirely symmetrical manner.

The flue on top of the furnace conducts the products of combustion to two vertical flues in the front of the furnace, from which

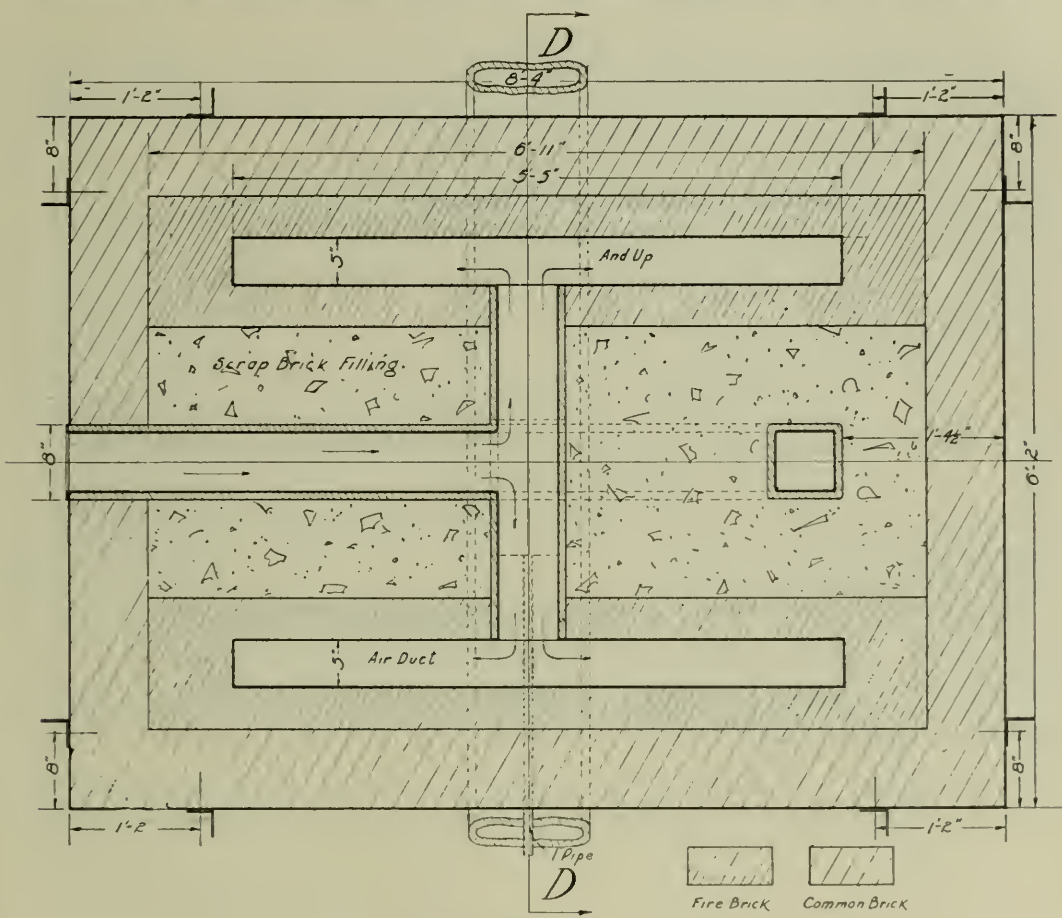


Section A-A

they pass into the large chamber directly under the furnace floor. This arrangement of the flues permits a greater transfer of heat to the front of the furnace which is normally the coldest portion, and removes a source of higher temperature in the already too hot rear of the furnace. The heat produced is, therefore, made almost completely to encircle the glass in the chamber, the rear alone being neglected in this respect. By actual test the tem-

perature was found to vary by not more than five degrees centigrade throughout most of the chamber. Near the door the temperature was slightly lower than in the chamber proper, as was to be expected.

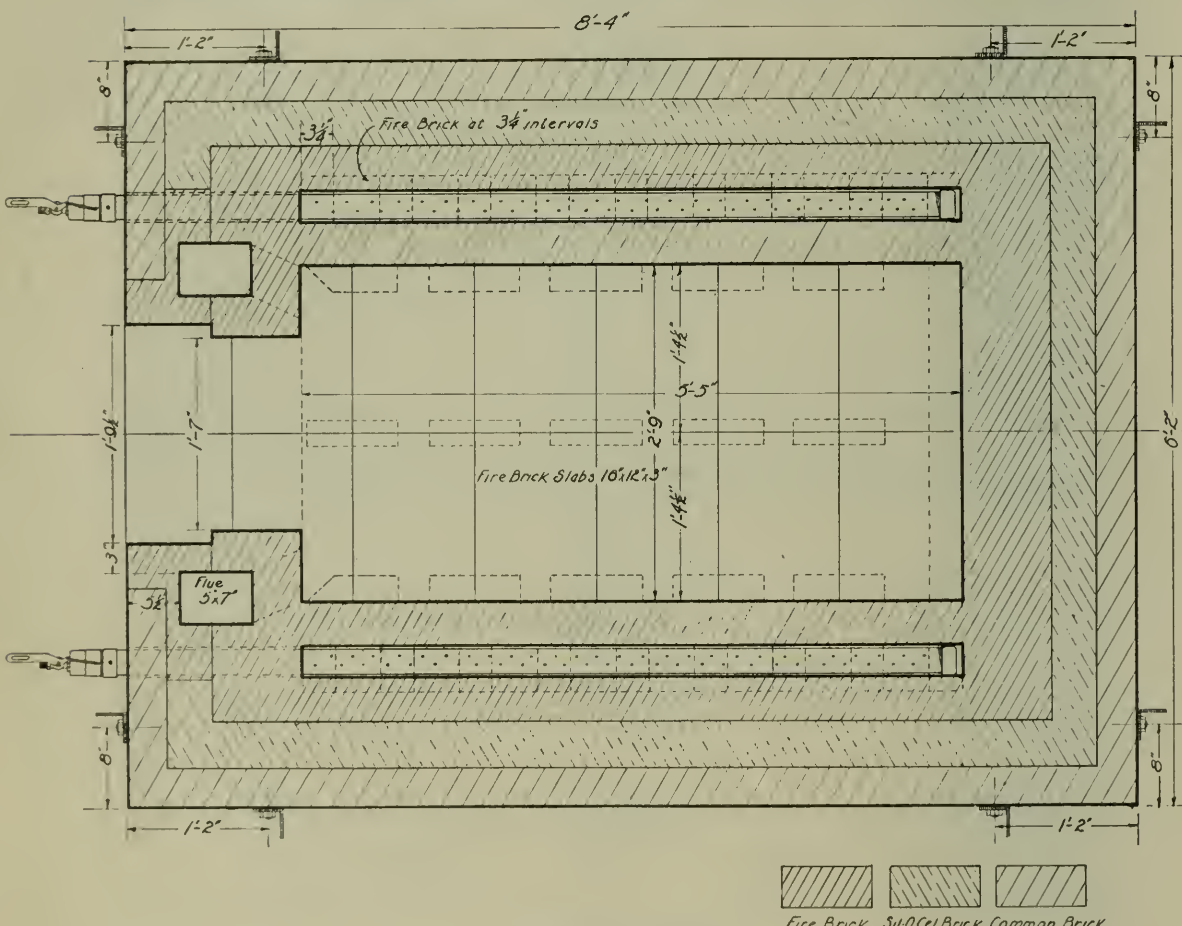
The mechanical construction of the furnace is easily ascertained from the figures. For the eight-inch red brick wall used



Section B-B

in the old furnaces, there was substituted four inches of red brick and four and one-half inches of Sil-O-Cel insulating brick. This additional insulation aided materially in reducing the loss by radiation and therefore the free cooling rate. At first this insulating wall was planned to be nine inches thick, but the thinner wall was decided on by reason of the necessity of building the new furnaces on the foundations of the old ones.

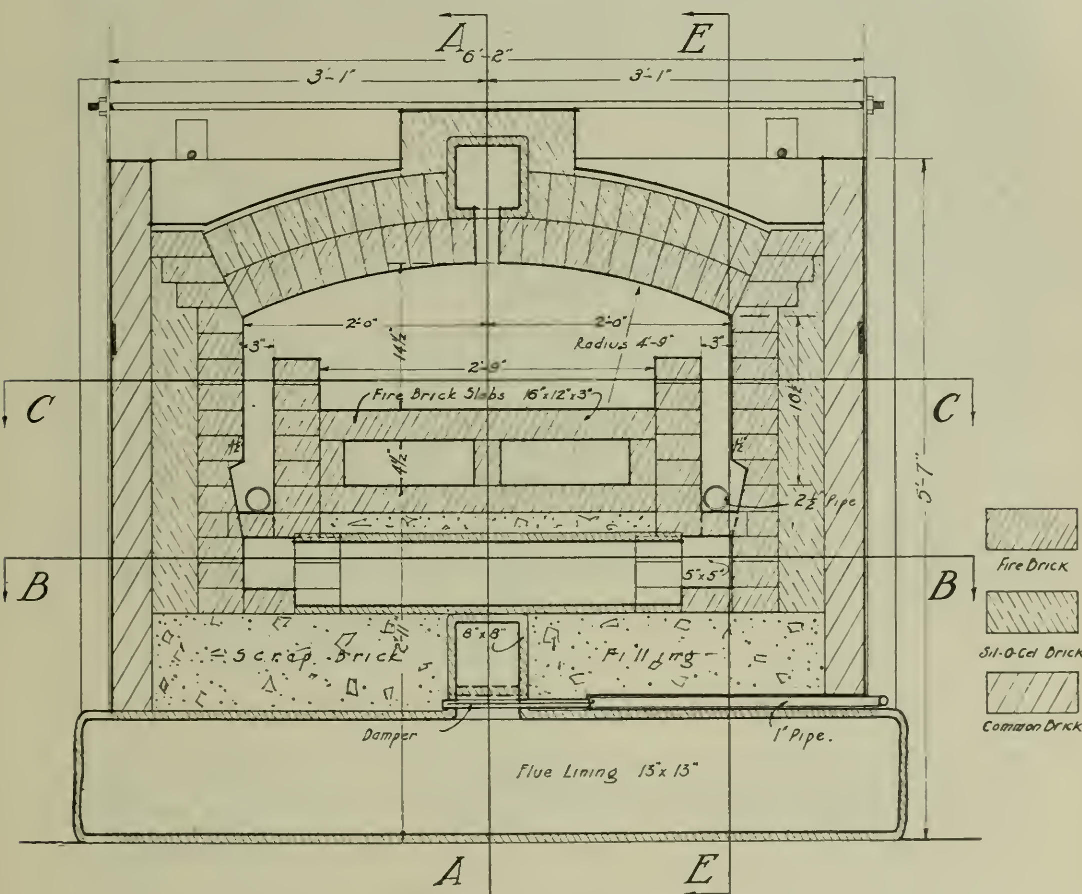
The operation of the furnace was very simple. The stack draft was opened, the gas turned on and lighted and the auxiliary air vent closed; as the temperature of the furnace increased the air vent was opened a little at a time and only enough to prevent the flame from becoming luminous. Any greater amount of air admitted would merely mean that the flame would be



Section C-C

cooled by the excess air. Peep holes which were cut through the front of the furnace and just above the burners, made it easy to ascertain the character of the flame when necessary. The furnace temperature having increased to the proper degree, the gas valve was set at the proper position to hold the temperature; this position being known by trial, and the air vent closed as far as consistent with proper flame conditions.

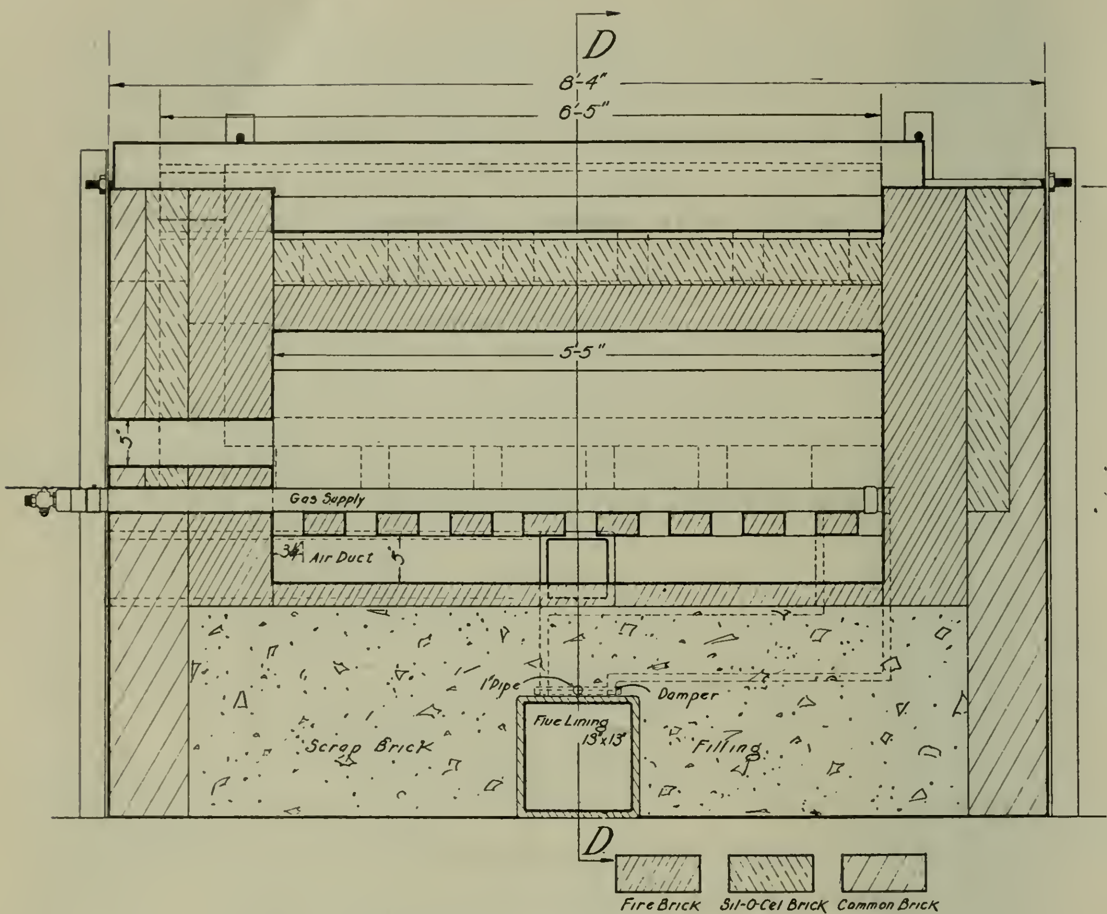
The work was then filled into the furnace, which took an average of nine hours time, and the annealing process started. If the schedule called for holding the furnace at a definite temperature this was accomplished with little attention from the operator, but the slow cooling over the first drop of 50 to 100 degrees necessitated more careful attention. The regulation



Section D-D

was accomplished by the manipulation of the main gate valve according to the personal judgment of the operator.

After the furnace had cooled to the point where its free cooling rate was so low as to prevent permanent strain, the gas was shut off and the dampers, peep holes and so forth, closed and sealed. After a drop of about a hundred degrees further, the stack dampers and air vent were opened slightly. From time to



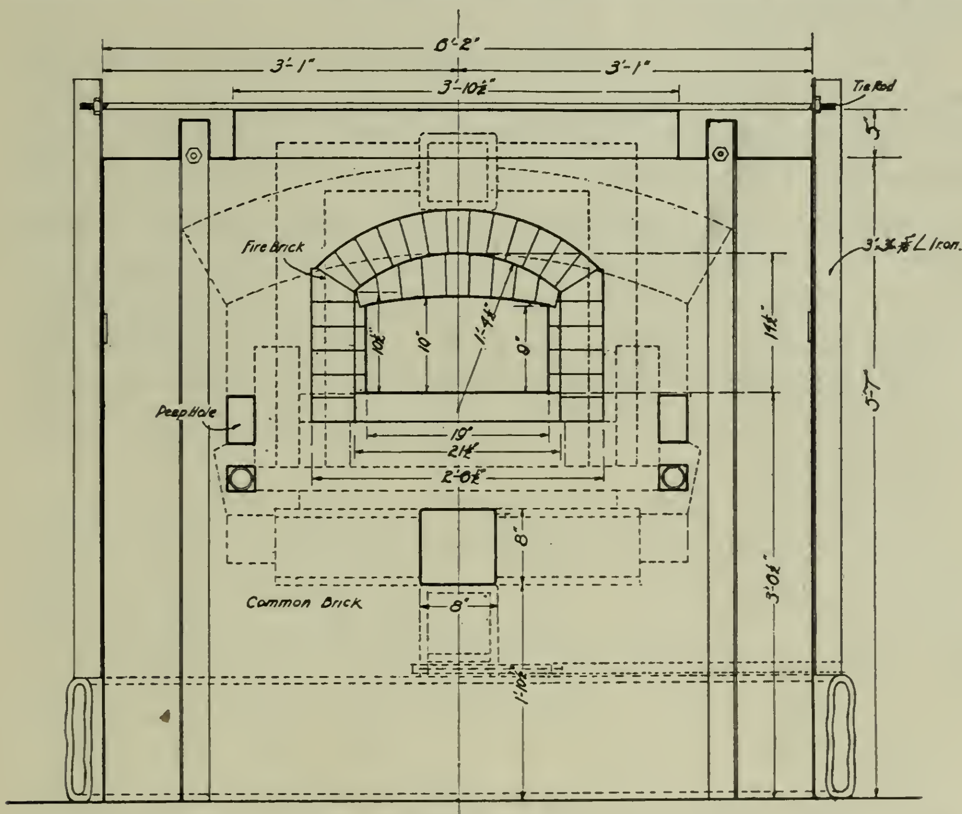
Section E-E

time these two dampers were opened wider to increase the cooling rate, until finally they were wide open. The furnace was then allowed to cool with no attention until the temperature was low enough to permit the door to be opened without the chance of dangerous temporary strain being set up in the glass.

The equipment used for temperature measurement consisted of Chromel-Alumel thermocouples, connected by compensating lead wire to a cold junction buried in the ground, and thence to a portable potentiometer. Actual measurements throughout the furnace proved that the temperature was so uniform that a single thermocouple encased in a one-half inch pipe extending through the top flue and crown into the furnace was sufficient. The end of the pipe was always lowered until it touched the glass. Tests

were made on the calibration of the couples at frequent intervals, although little variation was found and no trouble experienced from this source.

The results obtained by the use of this furnace have been quite satisfactory. An average furnace man, after a few days' experience, if provided with proper annealing schedules, could anneal one inch slabs to the grade of excellence called for in the regular commercial use of optical glass. By taking care in operating the



furnace, the author has succeeded in annealing large slabs two inches thick to about the practical limit of freedom from strain. A recent test of a slab annealed in this furnace showed a retardation of less than $2.5 \mu\mu$ per cm when the glass was examined in the usual manner in polarized light between crossed nicols.

The author does not claim that the above design could not be improved upon. In fact several changes could be made that might result in fuel economy and greater ease of control. The insulation, for instance, is important enough to justify a 9″ wall

of insulating brick in place of the $4^1/_2''$ wall. The expense of this extra wall thickness might be lessened by using a $4^1/_2''$ insulating brick wall, together with an air space between the former and the common-brick shell. One would expect about as good results from the air space insulation as from the extra $4^1/_2''$ of insulating brick. At low temperatures, *i. e.*, below 200°C, an air space would be a very efficient insulator, and the exterior surface of the original $4^1/_2''$ Sil-O-Cel brick wall should be at a lower temperature than this.

To test this latter conclusion, temperature measurements were made on the wall temperature of a furnace of this type. With the annealing chamber held between 400° and 500°C, the temperature in the center of the Sil-O-Cel wall varied between 120° and 130°C. The temperature at the center of the common-brick wall averaged between 70° and 74°C at the same time. These readings were taken with a mercury-in-glass thermometer inserted in holes drilled in the proper distance so that the bulb of the thermometer was at the center of the brick. Lead foil was packed around the bulb, and asbestos packing filled in the remaining space.

Havard[1] states that an air space is a better insulator than a two-inch common brick wall, if the temperature of the hotter surface is below 625°C. This is quite evidently an error, as his figures were taken from a bulletin of the Bureau of Mines,[2] and the original gives this limiting temperature as 625°C *absolute*, or 565°F, ordinary scale. This latter is also confusing, as it was doubtless meant for 665°F. It is evident that below 350°C, ordinary scale, an air space is as good an insulator as two inches of red brick. This limiting temperature would be lowered considerably, if an insulating material were employed in place of the red brick. It is unquestionable, however, that the air space would be as efficient an insulator under the conditions mentioned above, as the same thickness of insulating brick.

Another alteration in the construction, which might increase the efficiency of the furnace, would be the use of 13″ tile in place

[1] Havard, "Refractories and Furnaces," McGraw-Hill Book Co., 1912.

[2] *Bulletin*, No. 8, Bureau of Mines. "The Flow of Heat through Furnace Walls."

of 8″ in the flue, which takes the hot products of combustion from the chamber under the furnace floor. This flue could be made to run the entire length of the furnace before opening into the main flue leading to the stack. The main flue then must be placed at the front of the furnace. The 8″ auxiliary air flue, which has its inlet at the front of the furnace, could then pass through the inside of the 13″ flue tile, in such a manner that the heat in the latter would entirely surround the tile carrying the incoming cold air. The slight recuperative effect thus obtained ought to aid in maintaining a definite temperature and would undoubtedly result in economy in fuel.

Proper annealing schedules may be quite easily worked out from the information given by Adams and Williamson[1] if the annealing temperature of the glass is known. By using their method with this type of furnace, prisms and large blocks up to 10 cms in thickness have been satisfactorily annealed.

Spencer Lens Co.
Optical Glass Plant
Hamburg, N. Y.

[1] L. H. Adams and E. D. Williamson, *J. Opt. Soc. Am.*, **4**, 213 (1920).

THE TRANSVERSE STRENGTH OF FIRE-CLAY TILES AT FURNACE TEMPERATURES[1]

By R. F. Geller

ABSTRACT

Commercial fire-clay tiles, were tested at furnace temperatures, for transverse strength. This was supplemented by tests of tiles of known composition made in the laboratory. Moduli of rupture obtained varied from 245.5 pounds per square inch at 1275°C, to 28.9 pounds per square inch at 1350°C but the data collected do not warrant definite conclusions.

Introduction

There has been in the past an insistent demand for data regarding the transverse strength of fire-clay tiles at furnace temperatures for the purpose of guiding engineers in the design of metallurgical and other furnaces. The present work was intended to supply information on this subject as far as possible.

The investigation consisted essentially in the testing of commercial fire-clay tiles of different makes for transverse strength at different temperatures supplemented by tests of tiles of definite composition made in the laboratory.

Experimental

Tiles were secured from four manufacturing concerns, situated in Colorado, Missouri, Kentucky and Pennsylvania, and were marked, respectively: C, M, K and P. Two standard sized tiles were obtained, one being 12x12x2 inches and the other 26x9x3 inches.

The tile C showed very little iron discoloration. The grog varied from approximately eight mesh to the finest grades. The structure was fairly dense and had every appearance of a well balanced proportion between calcined material and the bond clay. The refractoriness of this tile, as well as that of the others, was satisfactory the softening points being equivalent to cone 31 or above.

Tile M possessed a dense structure but was spotted throughout with iron stain and slag. Blisters of $^1/_8$ inch or more in diameter

[1] Received April 30, 1921. Published by permission of the Director, U. S. Bureau of Standards.

were of common occurrence and quite uniformly distributed, indicating large amounts of ferruginous impurities. The average color was a dark buff and the fracture seemed to indicate that the body was composed mainly of fine quartz and bond clay, although some grog as coarse as four mesh and over was present.

Tile K was made of a buff burning clay, the body containing a large amount of coarse material. It showed innumerable fine cracks of about 1/4 inch in length, running parallel to the face of the tile and indicating a lack of fine grog, causing the bond to shrink away from the coarser particles.

The specimens marked P were composed of a white burning body showing no iron discolorations. Very little grog as coarse as eight mesh was in evidence and the structure as a whole was homogeneous and dense.

The method of testing followed in this work is similar to that given by the American Society for Testing Materials in its specifications for the determination of the resistance of fire-brick to load. Unless otherwise stated, the heating schedule given for heavy duty refractories in which the temperature is raised from 100°C to 1350°C in four and one-half hours was followed. The furnace used was of special construction and is shown in figure 1. It was first intended to fire two tiles simultaneously and a double loading device was provided. Owing to the uneven heating which the test specimens received, the furnace was altered so that only one tile could be tested. A baffle wall with checker work protected the tile from the direct flame and after a few trial runs the openings were so adjusted that the top and bottom sides of the specimen were practically uniform in temperature. Cones placed in various parts of the chamber showed no variation and these results were checked by means of a thermocouple. The special fire clay pieces used in supporting the tile and applying the load were made in the laboratory and consisted of

No. 1 fire-brick ground to pass the 10 mesh sieve	55%
Kentucky ball clay No. 4	15
Florida kaolin	15
Georgia kaolin	15

These were burned to cone 12 and gave very satisfactory service.

The furnace was covered with flat tiles 10x4 inches in cross section which at first caused considerable trouble by warping and cracking. This was due no doubt to the temperature gradient

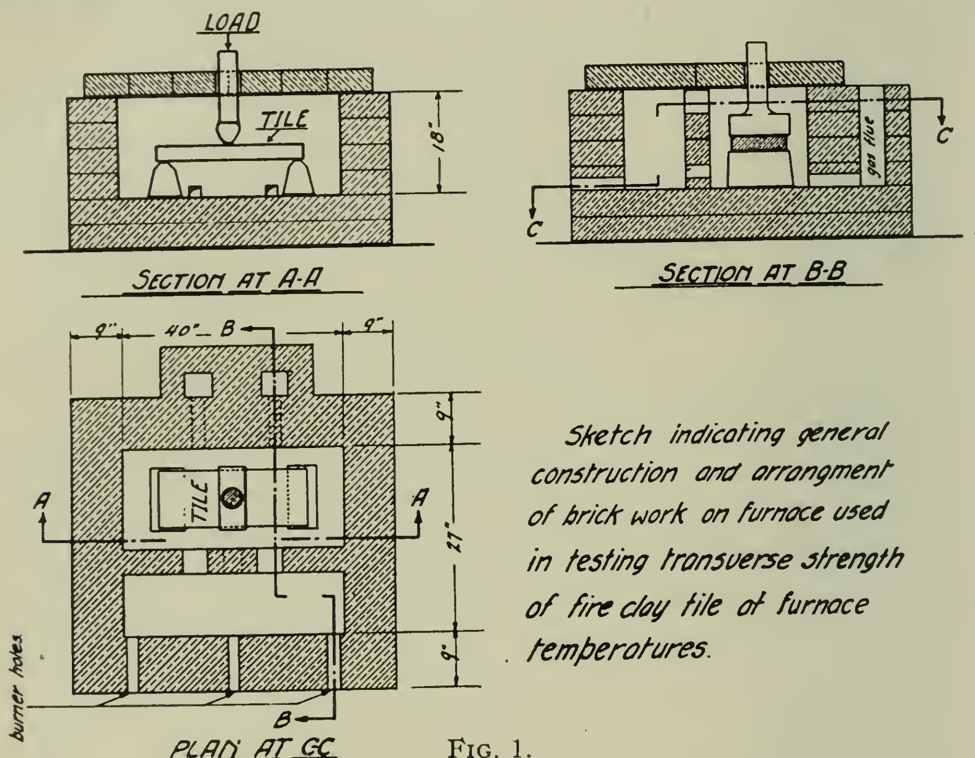


FIG. 1.

to which they were subjected, varying from 1350°C on the inside to approximately 100°C on the outside. Tiles of the following composition, burned to cone 12, were then made and no further trouble encountered:

Grog	(75% ground No. 1 fire-brick, 4 to 60 mesh) (25% ground No. 1 fire brick thru 60 mesh)	60%
	Tennessee ball clay No. 5	15
	Georgia kaolin	15
	Florida kaolin	10

The results obtained on specimens C are shown in table I.

In the first two burns the load was applied, until failure occurred, as soon as 1350°C was reached. The moduli of rupture lie fairly closely together, and when the load was applied at a lower temperature, as shown in the third burn, higher results were obtained, as would be expected. A greatly increased span (see runs 4 and 5)

TABLE I

Span in inches	Cross section, inches	Highest temp., °C	Load in pounds	Length of burn Hr.	Min.	Remarks
11	12″x2″	1350	84	4	30	M = 28.9 lbs./sq. in.
16	9″x3″	1350	113	4	37	M = 33.5 " " "
14	9″x3″	1325	209	4	15	M = 54.2 " " "
24	9″x3″	1325	20	4	15	Failed at this temp.
24	8 3/4″x3″	1275	20	4	00	" " " "
12	6″x2″	1320	20	4	20	" " " "
14	9″x3″	1300	20	6	30	Medium schedule Preheated to 425°C
6	6″x2″	1300	20	7	00	Medium schedule Preheated to 500°C

caused failure before the desired temperature was reached and the same was true in experiment 6 where the cross section was half of that in run No. 1.

It was then decided to preheat the tile slowly, to insure uniform thermal conditions, and to double the time element in the heating curve in order to guard against any strains resulting from a too rapid rise of temperature. As shown in runs 7 and 8, the tile actually proved weaker under these conditions. This would seem to indicate that failure occurred, not because of strains due to thermal changes, but to actual weakness of structure in the tile at high temperature. The load of twenty pounds was applied by means of the special fire-clay block which had this weight and which was used in breaking the tile. It was intended in the first place to serve for the transmission of the pressure from above. This weight rested on the specimen from the beginning of the burn.

No positive results were obtained from the tests of the tiles M. The data relating to this work are shown in table II:

TABLE II—TILE "M"

Span in inches	Cross section, inches	Highest temp., °C	Load in pounds	Length of burn Hr.	Min.	Remarks
12	11 3/4″x2″	1350	20	4	37	Failed at this temp.
20	9″x3″	1300	20	4	15	" " " "
12	9″x3″	1300	21	8	00	Medium schedule. Preheated 450°C
14	9″x3″	1275	20	7	30	Medium schedule. Preheated 450°C
12	11 3/4″x2″	1275	640	3	45	M = 245.5 lbs./sq. in.
24	9″x3″	1175	21	3	30	Failed at this temp.

The first two runs and the last resulted in failure. The first had not failed when 1350°C was reached although it had bent a little, but after holding seven minutes at this temperature, it gave way completely. With preheating and a more moderate firing schedule, shown in tests 3 and 4, the specimens had less strength, similar to tile C. In run No. 5, it was decided to apply a breaking load at a temperature of 1275°C since 1350°C appeared to be a critical point as related to the strength of the tile. A high modulus of rupture of 245.5 pounds per square inch was obtained, and is evidently due to the lower temperature employed.

Test pieces K composed of the buff burning body, containing a large proportion of coarse grog, gave rather poor results, as shown in table III:

TABLE III—TILE "K"

Span in inches	Cross section, inches	Highest temp., °C	Load in pounds	Length of burn Hr.	Min.	Remarks
16	9″x3″	1300	20	4	30	Failed at this temp.
18	9″x3″	1275	20	3	17	Failed at this temp. Preheated 275°C
14	9″x3″	1275	20	3	15	Failed at this temp. Preheated 275°C
24	9″x3″	1150	20	3	18	Slowly gave way at this temp.
$8^2/_3$	9″x3″	1350	447	5	30	Held at 1350°C for 1 hour. One-third of tile at each end held rigid in brick wall. M = 35.9 lbs./sq. in.

The first four burns resulted in failure before the maximum temperature of the heating curve was reached. As the data indicate, preheating again increased the weakness of the tile. It was then decided to alter the conditions of the test in order to more nearly approximate actual conditions under which tile are used. Accordingly, one-third of the tile at each end was firmly embedded in a brick wall. This left one-third of the tile, or eight and two-thirds inches, as a span between the walls. The temperature was raised to 1350°C as before, but held there for one hour before applying the critical load. A modulus of rupture of 35.9 pounds per square inch was obtained. The method of

testing described above was again applied to the tile P. In this case the specimen developed a modulus of rupture of 28.75 pounds per square inch which is less than that of tile K, although as the data given in table IV show, tile P in every other case appears to be stronger. Since the large mass of brick required to build the walls in this test caused an uneven distribution of heat, the results can not be considered of much significance and no more tests of this kind were made.

TABLE IV—TILE "P"

Span in inches	Cross section, inches	Highest temp., °C	Load in pounds	Length of burn Hr.	Min.	Remarks
18	9″x3″	1350	20	4	30	Failed
16	9″x3″	1350	464	5	00	M = 137.4 lbs./sq. in.
10	12″x2″	1350	83	5	00	M = 26.0 lbs./sq. in.
20	9″x3″	1325	20	4	15	Failed at this temp.
12	9″x3″	1300	20	8	00	Preheated to 450°C
10	6″x2″	1300	158	4	15	M = 98.7 lbs./sq. in.
6	6″x2″	1300	20	7	15	Preheated to 500°C. Failed
14	9″x3″	1175	20	7	00	Preheated to 275°C. Failed
$8^2/_3$	9″x3″	1350	314.3	5	30	Held at 1350°C for 1 hour. $^1/_3$ of tile at each end held rigid in brick wall. M = 28.75 lbs./sq. in.

Considering the other tests made on tile P, we again find, as shown in runs 5, 7 and 8, that preheating tends to weaken the tiles at the higher temperatures. Run No. 2 shows an abnormally high strength which can not be explained from the data at hand. The modulus of rupture obtained in test No. 3, however, agrees fairly well with that of tests 1 and 2, as shown in table 1. In run No. 6, the modulus of rupture of 98.7 pounds per square inch may not be inconsistent with others obtained considering that the tile was broken at 1300°C.

In order to test a specimen of known composition, a few tile were made at the Bureau of Standards. These tile burned to a very pale buff at cone 12 and were quite dense, the structure resembling that of tile C. They consisted of 40 per cent of silicious Arkansas fire-clay and 60 per cent grog. The grog was a calcined mixture of equal parts Kentucky ball clay No. 4 and Georgia

kaolin, ground to such fineness that 75 per cent graded from 10 to 60 mesh and 25 per cent passed through the 60 mesh screen. The data obtained relatively to these tiles are shown in table V.

TABLE V

Span in inches	Cross section, inches	Highest temp., °C	Load in pounds	Length of burn Hr.	Min.	Remarks
10	$2^7/_8$"x$8^1/_2$"	1350	20	8	00	Preheated 300°C. Held at 1350°C for 20 min.
$15^1/_2$	$2^7/_8$"x$8^1/_2$"	1350	75	7	30	Held at 1350°C for 1 hour. Load applied over $4^1/_2$ inch bearing surface
13	$2^7/_8$"x$8^1/_2$"	1350	150	8	00	Preheated 300°C. Load applied as above

Although a short span was used, the specimen in run No. 1 compares favorably with the commercial tile C considering that it was preheated and also held at 1350°C for twenty minutes before failure occurred. Tests 2 and 3 on the Bureau tile were made under somewhat different conditions. In place of knife edges, the tile were supported on bricks and the load also applied with a brick as the bearing surface. As the results show, considerably more strength was developed but it was obvious from the appearance of the fracture that the force exerted was not one of pure bending, but a combination of bending and shear.

In each burn the deflection of the tile at the center was observed by means of a cathetometer. A gradual lowering could be measured during the ten to fifteen minutes preceding the collapse of the specimen. After removing from the furnace the test pieces, however, showed no signs of softening or bending, failure in every case being due to a sharply defined break.

Conclusions

Sufficient data have not been obtained to warrant definite conclusions, but it would seem that:

(a) At the temperature of 1350°C commercial brick-clay tiles as now manufactured have very little transverse strength.

(b) Tiles containing comparatively fine grog, graded to produce a body having a minimum of voids, possess the greatest transverse strength at high temperatures.

(c) Transverse strength decreases rapidly with increase in temperature and vice versa as shown by the moduli of rupture obtained:

°C	Lbs. /sq. in.
1350	28.9
1350	33.5
1350	26.0
1325	54.2
1300	98.7
1275	245.5

(d) The test as now conducted is too rigorous to determine with sufficient accuracy the effect of small variations in the structure of the tile or the physical conditions of the test, *i. e.*, span, cross section and temperature.

The writer wishes to thank the manufacturers concerned for their interest in furnishing the tiles.

Bureau of Standards
Washington, D. C.

ACTIVITIES OF THE SOCIETY

New Members received during May, 1921

Associate Resident

Auld, F. Howard, The D. L. Auld Co., Fifth Ave. and Fifth St., Columbus, Ohio, General Manager.

Axford, Vincent, Jeffery-Dewitt Insulator Co., Kenova, W. Va.

Beeken, L. L., Jeffery-Dewitt Insulator Co., Kenova, W. Va.

Buck, D. M., American Sheet and Tin Plate Co., Pittsburgh, Pa.

Jones, Benjamin C., Pittsfield Porcelain Works of General Electric Co., Pittsfield, Mass., Superintendent.

Martin, Earle V., Forest Grove, Oregon.

Pfeiff, C. H., 145 Rector St., Perth Amboy, N. J., Superintendent, Plant No. 3, General Ceramics Co.

Schoneich, Philip A., Pittsfield Porcelain Works of General Electric Co., Pittsfield, Mass., General Foreman.

Associate Foreign

Glass, L. G., 603 Queens Ave., London, Ontario, Canada, Engineer, McClary Manufacturing Co.

Lax, Frederick, 37 Cross Flatts Ave., Beeston, Leeds, England, Managing Director, Lax & Shaw, Ltd.

Corporation

Washington Brick, Lime and Sewer Pipe Co., Spokane, Wash.

617

JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 4 August, 1921 No. 8

EDITORIAL

THE SUMMER MEETING

There is a family likeness among the meetings of the Society which take place from time to time. They partake of the characteristics of a social reunion and of a business convention. The meeting which assembled at Canton, Ohio, on the morning of July 25 was no exception. Perhaps it is rather a pity that one so often sees the same faces, but on the other hand there is in this a sense of brotherhood that would not be there if all were strangers. Yet there are always some who attend for the first time, to which may be added the significant remark that nearly all of these say they will surely come the next time.

The forenoon of the first day was spent in inspecting the huge plant of the Dueber Watch Case Company, a place where not only the cases but the complete watch, from the swaging of the filled bars of metal to the enameling of the face and the printing of the hours on the dial, may be seen in process of production. Only a few workers were employed but there was somebody at work at every job.

After luncheon the party, now about one hundred strong, proceeded to the plant of the Canton Stamping and Enameling Company, where a uniform grade of granite household ware is produced. The whole process was carefully explained by Royal W. Taylor and his assistants and the visitors were even permitted to enter the mixing room.

Toward evening two large buses appeared at the hotel and these, supplemented by numerous private cars, conveyed the crowd to Congress Lake, eighteen miles away, where at the Country Club an excellent dinner was served. There was, of course, the usual provision for dancers but the ladies were greatly in the minority, so that it was announced to be in order that any man might "cut in" as he pleased.

After dinner there were two or three brief speeches and a story telling entertainment by a well known raconteur. Mr. Stull announced that a presentation was to be made to Professor Binns and a steward started up the hall with a huge glass punch bowl. Upon reaching the center of the table he conveniently slipped and fell so that the bowl was removed by a broom and dust pan to the relief of the donee.

Tuesday morning was devoted to the plant of the Alliance Brick Company which was reached by automobile. Here was seen an admirably equipped plant making rough faced brick and a new Richardson Chamber Kiln fired by producer gas. At the Alliance Country Club an excellent luncheon was served to the party which now numbered one hundred and fifty. The next move was to Sebring where were visited the plants of the Sebring Pottery Company, the Limoges China Company, where a newly installed tunnel kiln was the center of attraction, and the Strong Enamel Manufacturing Company. A special car conveyed the members back to Canton where an evening's entertainment in the form of a smoker was provided.

On Wednesday morning an early start by motor bus and automobile was made for East Liverpool which was reached about half past ten. The R. Thomas & Sons Company's plant was visited at once and at noon a liberal luncheon was served at the Elk's Club, which place also provided a hospitable headquarters during the day. After luncheon Mr. W. E. Wells gave one of his inimitable addresses and then the street cars conveyed the crowd to the mammoth plant of the Homer Laughlin China Company across the river. Here different groups were conducted by guides for the inspection of equipment and process and a profitable time was spent.

The Edwin M. Knowles China Company's plant was then visited and the party returned to the Elk's Club to separate finally for the journey home.

It is difficult to compare one meeting with another and as the membership grows it is to be expected that numbers will increase but it is certainly true that the meeting of 1921 was the largest and most generally enjoyed of any in the history of the Society. Much of this success is due to the efforts of Ira E. Sproat and the local committee of which he was chairman. Resolutions of thanks to them and to the firms who generously assisted were passed at the Wednesday luncheon.

ORIGINAL PAPERS AND DISCUSSIONS

THE CAUSES AND CONTROL OF FISH SCALING OF ENAMELS FOR SHEET IRON AND STEEL [1]

By R. R. Danielson and W. H. Souder

ABSTRACT

Data obtained.—This paper presents measurements of the following factors and properties and their influences upon fish scaling in the case of typical single and three-coat enamels: time and temp. during melting of the frit; fusibility of the enamel; coeff. of expansion of the enamel, and of a variety of representative irons and steels up to 500°C (accuracy about 0.1%); annealing the enamel coat after firing; chem. comp. of the steels and irons; mechanical treatment (rolling, spinning, drawing, and so forth of the stock; microscopic surface structure of the stock; effect of chem. comp. upon thermal expansion of enamel.

Incidentally it was found that the formulas of Mayer and Havas for computing the thermal expansion of enamel from its chem. comp. can not be relied upon.

Conclusions.—On the basis of these exhaustive tests, the following conclusions have been drawn as to the causes and the control of fish scaling. (A) Causes.—1. The cause of fish scaling lies in the difference of the coefficients of expansion of the enamel and the stock, that for steel being higher than for enamels so that the latter are under a compressive stress. The factors influencing this phenomenon are as follows: (*a*) Composition of the enamel as affecting the coefficient of expansion of the enamel; (*b*) Overfiring—thus volatilizing those substances which tend to keep the coefficient high; (*c*) Lack of annealing enameled ware, the enamel coating of which is a *glass* and should logically be treated as such.

2. Fish scaling is due secondarily to a number of factors which may affect the strength of the enamel or its adherence to the metal. (*a*) The physical condition of the surface of the metal as influenced by drawing, spinning, cold rolling or other mechanical treatment; (*b*) Composition of the glass as affecting its elastic strength; (*c*) Underfiring, enamel not fused to metals; (*d*) Cleanliness of the surface as regards removal of drawing compounds, grease, etc.

[1] Received June 13, 1921. Published by permission of the Director, Bureau of Standards.

(B) **Remedies.**—1. (*a*) Adjusting the composition of the enamel so as to increase its coefficient, *e. g.*, by decreasing the boric acid content; (*b*) Correct firing of the enamel to avoid unnecessary volatilization of such fluxes as soda and cryolite; 2. (*a*) Adjusting enamel composition to increase its strength; (*b*) Correct firing to give proper adherence. 3. Treatment of metal to give best adhesion by (*a*) cold rolling or other suitable mechanical treatment of the untreated steel; (*b*) thorough cleaning.

(C) **Summary.**—Broadly stated, then, fish scaling can be absolutely controlled by one or all of the following methods: (1) By the development of an enamel with an expansion fitting the metal; (2) by annealing the enameled ware; (3) by treatment of the metal as cold rolling or some other method of working; (4) by developing an enamel with a wide range of compressional elasticity and applying this enamel to metal treated as indicated above.

The subject of fish scaling of enamels has been much discussed among enamelers but comparatively little systematic investigation has been carried out in spite of the enormous losses occasioned in the industry by this defect, the only work recorded being that of Shaw.[1] Fish scaling may be defined as the spontaneous chipping or scaling of small particles of enamel from an enamel surface. These scales may vary from $^1/_{64}$ to $^3/_8$ of an inch in diameter and appear to be confined to the enamel surface although on close examination they are usually found to extend down to the steel, the extent of fracture depending on the type and size. The smaller scales are usually very numerous while the larger type are generally few in number.

The Enameled Metals Section of the Bureau of Standards has been conducting during the past year and a half an extended investigation of this subject, and preliminary reports were presented at the annual meeting of the American Ceramic Society in February, 1920, and also at a joint conference of the Enamel Division of the Society and the Sheet Metal Ware Manufacturers Association at this Bureau, June 15, 1920. In attacking this problem, the initial work was done on gray ware enamels since these are the least complex in composition and in method of application. As a basis for the compounding of the enamels, an average of several commercial formulas, having the following composition, was selected:

[1] J. B. Shaw, "Fish Scaling," This Journal, 3, 489–98 (1920).

	Raw batch per cent	Raw batch for 100 lbs. melted	Melted per cent	
Feldspar	49.0	62.5	62.5	
Borax	35.0	45.0	16.3 B_2O_3	
			7.45 Na_2O	
Soda ash	7.8	10.0	5.8 Na_2O	14.7
Soda nitre	3.1	4.0	1.45 Na_2O	
Bone ash	3.5	4.5	4.5	
Antimony oxide	1.6	2.0	2.0	
	100.0	128.0	100.0	

Empirical formula	0.285 K_2O	0.285 Al_2O_3	1.72 SiO_2
	0.600 Na_2O	0.600 B_2O_3	
	0.115 CaO	0.018 Sb_2O_3	0.076 $(PO_4)_2$

The composition of the frit is based on the assumption that such materials as feldspar, bone ash, antimony oxide, and cryolite lose no weight during melting. The method of calculation is similar to that described by Staley in his treatise on enamels for cast iron.[1]

The results of preliminary experiments and the desire to bring out clearly the effect of feldspar on fish scaling showed the advisability of working with three groups of enamels, so arranged that the feldspar remained constant in any group, the variations being made in the fluxes. The feldspar content was set at 59 per cent, 62.5 per cent, and 66 per cent, respectively, the preliminary experiments having demonstrated that these about covered the field of workable enamels. The groups shown in tables 1 and 2 have served as the basis for the work on the gray ware enamels.

Table 1—Composition of Melted Enamels

Material	Constant parts		
	59% feldspar group	62.5% feldspar group	66% feldspar group
Feldspar	59.0	62.5	66.0
Sodium oxide	10.0	10.0	10.0
Boric oxide	14.0	14.0	10.5
Fluorspar	3.5	0.0	0.0
Bone ash	4.5	4.5	4.5
Antimony oxide	2.0	2.0	2.0
Variable	7.0	7.0	7.0
Totals	100.0	100.0	100.0

[1] H. F. Staley, "Manufacture of Cast Iron Enameled Ware," *B. S. Tech. Paper*, No. **142** (1919).

Material	Amount	Enamel	Variable parts, Enamel	Enamel
Sodium oxide	7	A-20	A-1	A-16
Boric oxide	7	21	2	12
Fluorspar	7	22	3	17
Cryolite	7	23	4	18
Sodium oxide / Boric oxide	3.5 / 3.5	24	6	9
Sodium oxide / Fluorspar	3.5 / 3.5	25	7	19
Boric oxide / Fluorspar	3.5 / 3.5	26	10	14

Additions for direct increases of feldspar

21*a*—Enamel 21 plus 5% feldspar
21*b*—Enamel 21 plus 10% feldspar
23*a*—Enamel 23 plus 5% feldspar
23*b*—Enamel 23 plus 10% feldspar

TABLE 2—BATCH COMPOSITION OF ENAMELS—WEIGHTS OF RAW MATERIALS TO GIVE 100 PARTS MELTED

Material group	Constant parts 59% feldspar group	62.5% feldspar group	66% feldspar group
Feldspar	59.0	62.5	66.0
Sodium nitrate	4.0	4.0	4.0
Soda ash	4.0	4.0	6.7
Borax	38.2	28.2	28.7
Fluorspar	3.5	0.0	0.0
Bone ash	4.5	4.5	4.5
Antimony oxide	2.0	2.0	2.0

Material	Amount	Enamel	Variable parts, enamel	Enamel
Soda ash	12	A-20	A-1	A-16
Boric acid	12.4	21	2	12
Fluorspar	7	22	3	17
Cryolite	7	23	4	18
Soda ash / Boric acid	6.0 / 6.2	24	6	9
Soda ash / Fluorspar	6.0 / 3.5	25	7	19
Boric acid / Fluorspar	6.2 / 3.5	26	10	14

Additions for direct increase in feldspar

21*a*—Enamel 21 plus 5 parts feldspar
21*b*—Enamel 21 plus 10 parts feldspar
23*a*—Enamel 23 plus 5 parts feldspar
23*b*—Enamel 23 plus 10 parts feldspar

The various enamels were compounded by weighing up the base enamel in each group and adding to it the required amount of flux to produce the desired composition. For example, A-20 was made by weighing the raw materials listed in the 59% feldspar group (table 2), and adding to it 12 parts of soda ash. A-2 was compounded by weighing the base for the 62.5% feldspar group and adding to it 12.4 parts of boric acid. The complete batches were then mixed for melting.

For preliminary tests, the enamels were weighed in 4.5 lb. batches, mixed thoroughly by hand and by sieving. These were then melted in fire-clay crucibles in a pot furnace. An attempt was made to keep a uniform melting temperature, a number of readings with an optical pyrometer indicating a temperature of about 1170°C (2140°F).

The average time of melting was about one hour, the operation being carried to a point where the melt was as free from bubbles as possible under the conditions of crucible melting. The melts were quenched in water, dried and then ground wet in porcelain ball mills, the following mill batches being used:

Frit	1000 grams
Clay	60 "
Magnesium carbonate	5 "
Water	55 ccm.

The batches were ground for seven hours which was sufficient to permit them to pass an 80 mesh sieve.

The enamels were then applied to 2 × 3 inch plates of a 20-gauge iron, hereafter designated as Iron A (see table 4). These had been prepared by boiling in a solution of caustic soda for about 20 minutes to remove oil, then rinsed in clear water and pickled in a hydrochloric acid bath of one part acid (1.18 sp. gr. 36% HCl), to seven parts water. This gave an acid content of about 5.5 per cent.

After pickling, the plates were rinsed several times in water and were then kept under water until ready for the application of the enamels. The latter were applied by dipping, epsom salts being used as the flotation medium. The plates were then dried and were ready for firing.

A definite firing schedule was established to determine the effect of variations in firing, so that there might be a basis of comparison for various enamels under the same heat treatment. The following schedule was made broad enough to cover the range of the various enamels:

Temperature in degrees C	F	Time in minutes		
760	1400	2	4	6
820	1508	$1^1/_2$	3	$4^1/_2$
880	1616	$1^1/_4$	$2^1/_2$	$3^3/_4$
940	1724	1	$1^1/_2$	2

Ten samples of every enamel were made for each temperature and firing period. The plates were fired in a Hoskins electric muffle furnace and were supported on a grid of wrought iron which was left in the muffle continuously in order to keep it at furnace temperature. A platinum platinum-rhodium thermocouple enclosed in a very thin porcelain tube was placed directly over the plates and, the muffle being about 6 × 8 × 12 inches, the temperature could be regulated fairly accurately within 10°C of the accepted standard.

Effects of Variations in Composition and in Firing

The following conclusions can be drawn from this phase of the work:

(1) In a normal enamel fish scaling increased with increase in temperature or length of time of firing beyond normal firing conditions.

(2) Too low a temperature or too short a firing period produced blistering and bubbling, while high temperatures and long periods resulted in burning off of the enamel.

(3) Considering only those results in which the enamels were properly fired, the following order gives the relative effects of various fluxes in reducing fish scaling, the most effective being placed first:

a. Cryolite
b. Fluorspar
c. Sodium oxide
d. Boric oxide

(4) The burning range of the enamels is lengthened by the

following materials in the order named, the most effective being noted first:

a. Cryolite
b. Fluorspar
c. Boric oxide
d. Sodium oxide

Fusion Tests of Enamel

On the basis of the above results, it was assumed that this "fish scaling order" of the fluxes followed the relative fusibilities of the enamels, but further work has proven otherwise. Fusion tests of cones prepared from these enamels have placed the fluxing action of the materials in the following order, the first named giving the most fusible enamels:

a. Cryolite
b. Sodium oxide
c. Fluorspar
d. Boric oxide

These determinations were checked by melting small layers of

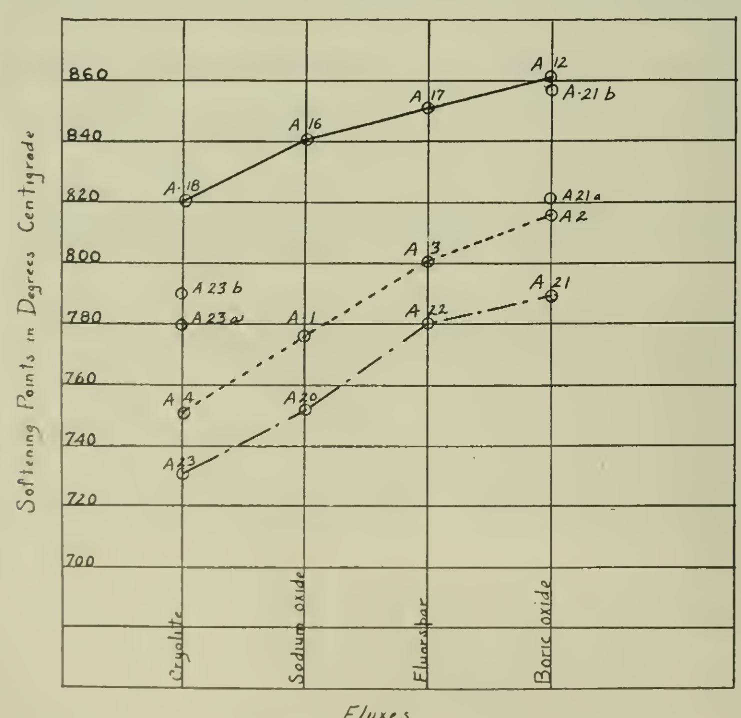


FIG. 1.—Relative fusibilities of gray ware enamels.

enamels on ground coated plates at various temperatures for periods of two minutes and noting the temperature at which the enamels fused. These temperatures, while not agreeing with the softening points of the cones, place the fluxes in the same relative position as shown in the curves, figure 1.

Effect of Variations in Smelting Procedure

To determine the effect of over- and under-smelting, the first four enamels, A-1, A-2, A-3, and A-4, of the group containing 62.5 per cent feldspar were selected. Three batches of each enamel were made and melted as described previously but with the following changes in the duration of melting. The under-melted batch was carried to the point where all the raw materials were apparently melted, no attempt being made to drive off the gases. This required on an average about 40 minutes. The medium melted enamels were melted until the gases had been driven off and the melt had become quiescent. This required on an average about 55 minutes. The over-melted enamels were held at this same point for about 15 minutes longer, giving on an average about 70 minutes. These enamels were prepared and applied, as described previously in this paper, to 2×3 inch plates of Iron A and a steel designated as Steel B.

The following conclusion may be drawn as to the effect of various treatments in melting:

(1) Increasing the time of melting of an enamel has apparently but slight effect on the tendency to fish scale. It must be remembered, however, that while the melts were apparently over-melted in 70 minutes, the increased effect of melting is probably not as great as that encountered in actual practice where the results tend to show that over-melting increases fish scaling, undoubtedly due to the volatilization of fluxes like sodium oxide[1] which tend to decrease fish scaling.

The effect on fish scaling of variation in the steel is very apparent in this part of the investigation since the scales on Steel B are much larger than those on Iron A.

[1] Poste and Rice, "Effect of the Degree of Smelting," THIS JOURNAL, **1**, 221–37 (1918).

A number of these gray ware enamels typical of those prone to fish scale and others free from this defect have been applied to the various steels and irons listed in tables 4, 5, 6, and 7. The general results confirm those obtained with Iron A and Steel B although there is a tendency on the part of certain stocks to develop a greater or less tendency to fish scale even when coated with the same enamels. Steels C and D, for instance, which are cold rolled strip steel, although not considered as enameling stock, show a complete freedom from the defect. It is evident therefore that further consideration must be given to the various properties of the stocks such as expansivity, chemical composition, mechanical condition, and so forth. These have been carefully studied with the results shown in the following sections.

Thermal Expansion of Enamels

The foregoing studies have indicated that composition and heat treatment of the enamel have a marked effect on fish scaling. There are variations in some of the results which undoubtedly are consequences of improper manipulation. There still remains, however, the fundamental problem of why enamels fish scale and an explanation for the variations in results obtained with various steels and irons.

Because of the nature of the defect, the most logical place to look for the solution is in the relative thermal expansivities of the enamels and stock. Tabulated values of coefficients of expansion for iron and steel usually indicate a value of 12×10^{-6} to 13×10^{-6} per °C. Empirical formulas for the enamel values in terms of composition have been supplied by Winkelman and Schott and by Mayer and Havas.[1] By using these formulas it has long been considered possible to mix an enamel which will match the stock. We are all familiar with the attempts and failures of this method. A further confusion has arisen due to the fact that different specimens of stock of practically the same expansive qualities have shown different results. With these contradictions and indefinitenesses hindering further progress, it was decided to make a comprehensive survey of the subject of

[1] Mayer and Havas, "Coefficient of Expansion of Enamels and Their Composition," *Sprechsaal*, 44, 188 (1911).

expansion, disregarding for the time being all previous work on this phase by other investigators.

In this work the regular equipment of the Expansivity Section of the Bureau was utilized, the accuracy of which may be stated as 0.1 per cent.

For the study of the metal stocks a number of representative irons and steels were selected and strips were cut from the plates approximately one inch wide and 14 inches long. In commencing the work on enamels, specimens were prepared from both the molten frit and the enamel prepared for dipping, but no difference was observed so the work was continued on the latter alone.

The specimen rods of enamel were 14 inches long and triangular in cross section, being about $^3/_8$ inch along a side. These were prepared by drying the enamel slip, placing the resulting powder in sheet iron troughs lined with asbestos paper and melting the powder to an enamel rod in the enameling furnaces at approximately enameling temperatures. This required about five minutes, after which the troughs and contents were removed to an enameling furnace at 500°C (932°F) and cooled slowly to room temperatures.

In the expansivity furnace, the specimens were supported horizontally in quartz tubes. V-shaped rings were cut around the specimens near each end so that 2-mil annealed platinum wires could be fastened in these. Each wire, hanging through a hollow tube below the end of the specimen and extending downward through and below the furnace, had at its lower end a vane (or weight) immersed in oil in order to dampen the vibrations. Heating was effected by electric resistance coils (outside, inside, and end coils). With careful manipulation it was possible to adjust the circuits so that during an observation the specimen was at a uniform temperature within 0.1°C, from end to end.

The length changes were determined with a comparator consisting of two microscopes rigidly clamped on an invar bar at a distance from each other equal to the distance between the grooves of the specimen (30 cm.). The microscopes were so arranged that they could first be sighted on a standard-length bar kept at constant temperature, and then on the vertically suspended wires which were in the grooves at the ends of the specimen.

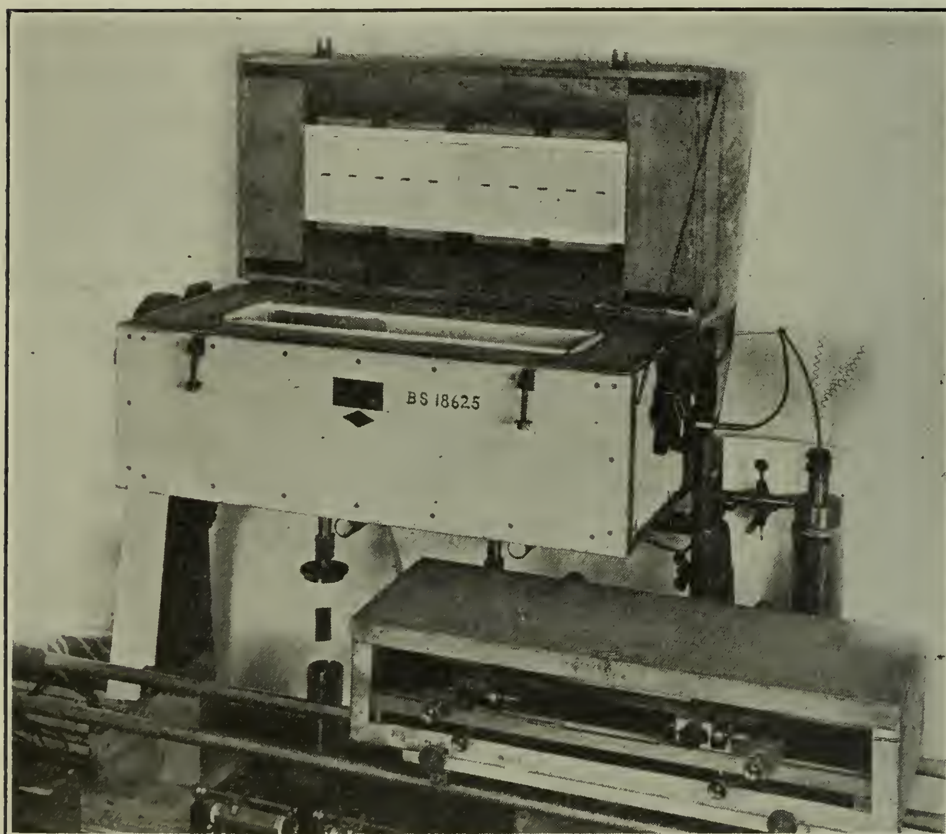


FIG. 2.—Expansivity apparatus.

The apparatus shown in figure 2 was used for this research. This figure portrays the essential method of making observations on materials. The furnace is shown with the top lifted. The traveling microscopes, which are sighted (simultaneously) on the two vertical wires hung from the specimen, are displaced to the right in order to show the construction of the tube protecting the vertical or drop wires. The left oil pot is removed to show the weight attached to the wire.

The temperatures in the furnace were determined by means of a platinum platinum-rhodium thermocouple. It had been noted that enamels became viscous on enameled plates at about 550°C (1020°F) so it was decided to make the expansion studies between room temperatures and 500°C.

Table 3—Coefficients of Expansion × 10^6

Gray Ware Enamels and Steels

Enamel	1. Room to 200°C	2. Room to 400°C	3. Room to 500°C	4	5	6
A-1	10.9	11.3	13.9	11.7	0.8	0.4
A-2	8.8	9.4	10.7	9.4	.6	.0
A-3	9.4	10.7	13.2	9.9	1.2	.8
A-4	9.8	11.6	13.4	11.0	1.2	.6
A-12	8.2	9.3	10.6	9.7	1.5	.4
A-16	9.4	10.1	10.8	12.0	2.6	1.9
A-17	9.1	10.2	11.9	10.2	1.1	.0
A-18	9.3	10.4	12.6	11.3	2.0	.9
A-20	10.1	10.9	13.8	11.6	1.5	.7
A-21	8.1	10.1	11.3	9.3	1.2	.8
A-21*a*	8.1	9.0	10.2	9.2	1.1	.2
A-21*b*	8.3	9.1	10.5	9.2	.9	.1
A-22	9.5	10.6	13.7	9.8	.3	.8
A-23	10.0	11.4	13.8	11.0	1.0	.4
A-23*a*	8.8	10.4	11.8	10.9	1.1	.5
A-23*b*	9.3	10.6	13.5	10.7	2.0	.1
Steel A-A	12.7	14.1	14.6			
Steel A-B	12.7	14.1	14.5			
Steel A-D	13.1	14.2	14.6			
Steel C-*hd*	12.6	14.2	14.5			
Steel C-*an*	12.9	14.1	14.8			
Steel C-*an-el* 25%	12.7	13.8	14.2			
Steel B	12.8	14.0	14.4			
Iron A	13.0	13.9	14.4			
Iron A-*el* 20%	12.7	14.0	14.6			

(1, 2, 3) Observed values for coefficients of expansion of enamels and steel from cooling curves.

(4) Calculated values of coefficients of expansion from Havas and Mayer's values.

(5) Calculated values compared with Bureau observation—room to 200° C, differences.

(6) Calculated values compared with Bureau observation—room to 400° C, differences.

The values for the various steels and enamels studied are given in table 3, as well as the figures computed from the values given by Havas and Mayer[1] for various oxides. In figures 3, 4, and 5 are shown the curves for the various enamels as compared with steel.

In these curves the temperatures are plotted as abscissas and the expansions per unit length as ordinates. The expansion

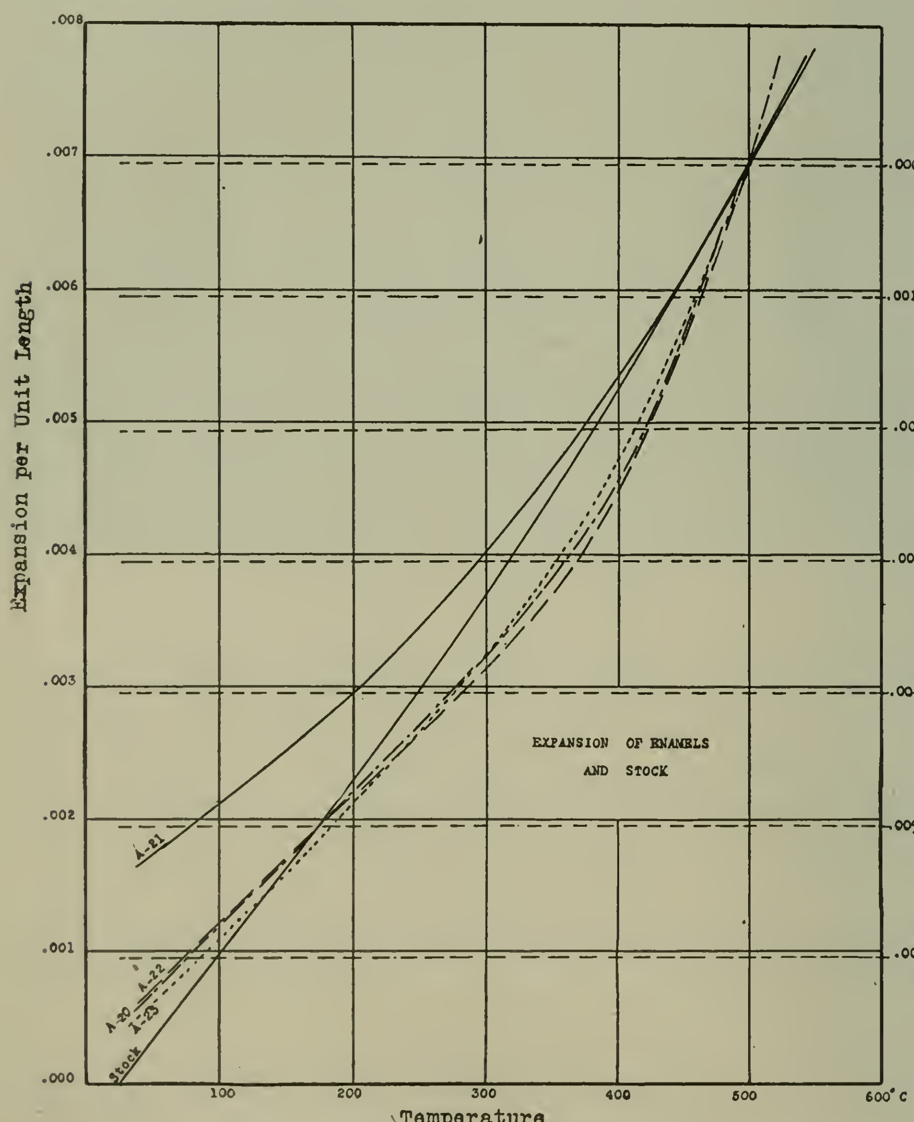


FIG. 3.—Expansion of enamels A-20 to 23 and stock matched at 500°C.

[1] *Loc. cit.*

for the stock was plotted first, and, for the reasons stated above, the enamel expansions plotted to agree with the stock at 500 °C. The actual total expansion of stock per unit length, from room to any higher temperature, may be read directly at the left of the curve. In getting the actual expansions of the enamels between any two temperatures it will obviously be necessary to take the difference of the two readings at the left corresponding to the respective values of the temperature interval.

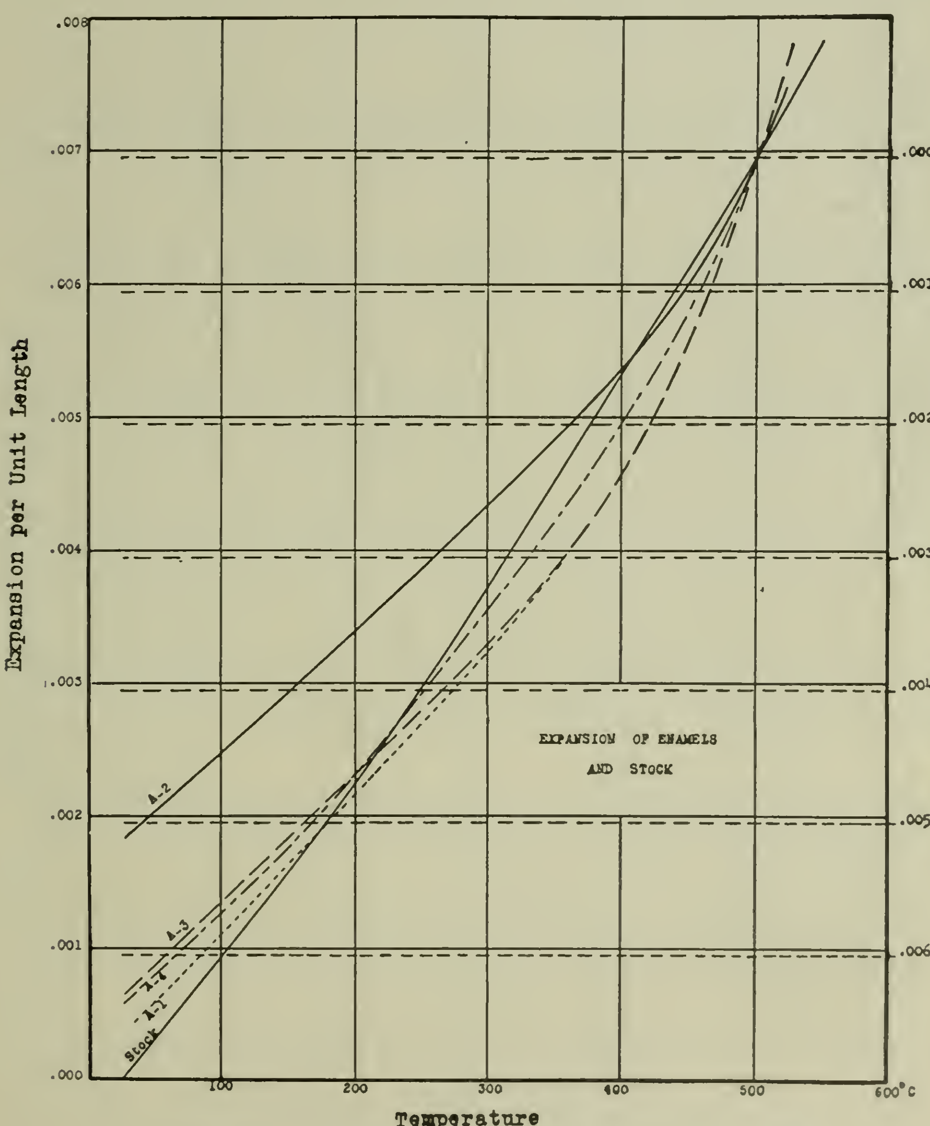


FIG. 4.—Expansion of enamels A-1 to 4 and stock.

A brief discussion of the above is appropriate at this time. Heat and mechanical treatments failed to modify the expansivities of these stock steels and irons, which is contrary to the results in cast iron enameling where growth of the iron casting is encountered as a result of heating. The values of the coefficients of expansion of the various stocks in table 3 will be found so nearly the same that an extended discussion is not necessary at this

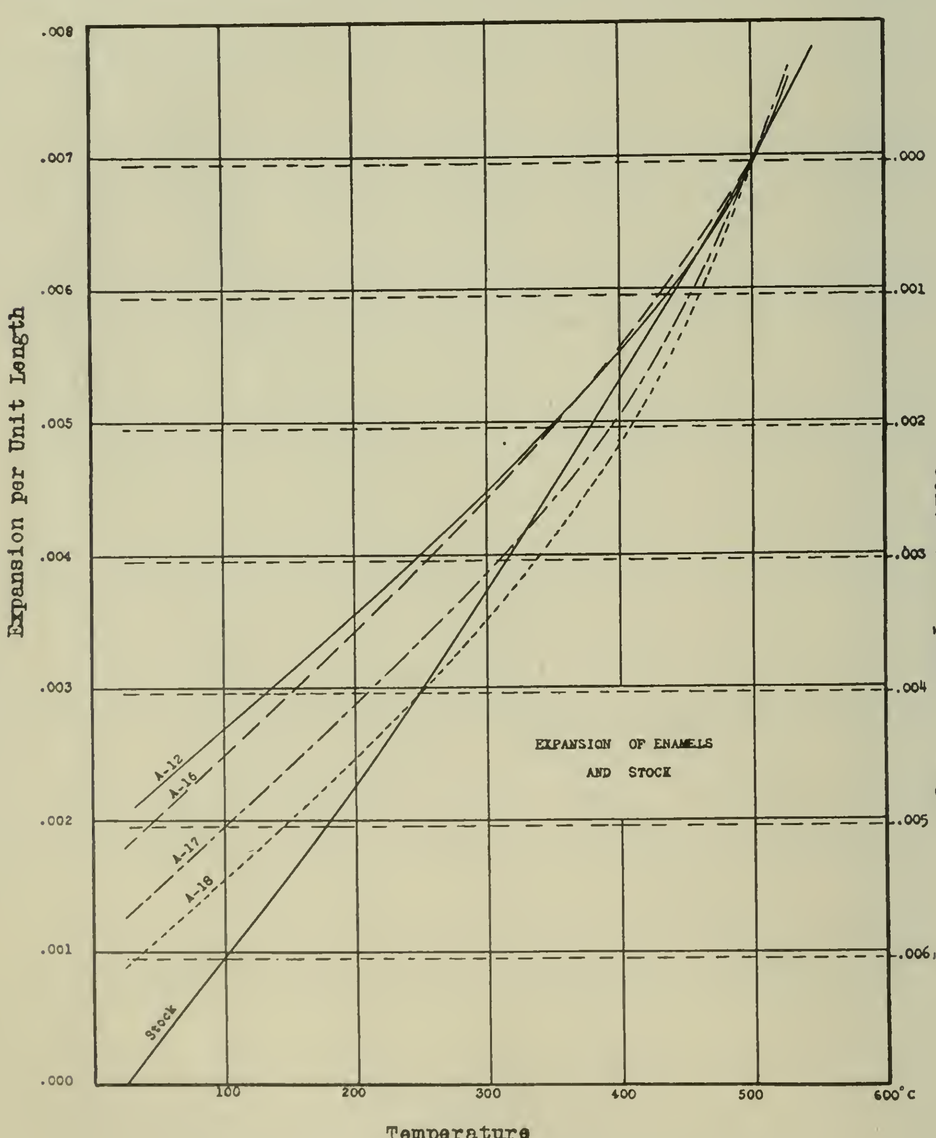


FIG. 5.—Expansion of enamels A-12 to 18 and stock.

time. The letters (*hd*) after specimen C refer to hard cold rolled material. Similarly (*an*) indicates annealed and (*el*) indicates elongated or stretched in the tensile apparatus.

From a study of these values it is evident that cold rolling, annealing, stretching, and so forth, have only a negligible effect, if any at all, on the expansivities of stock. Furthermore, the general character of the heating and cooling curves obtained in these tests show that no permanent changes were introduced in the material (so far as expansivity is concerned) since they all returned to their original lengths after testing.

The enamel expansions are lower than those for steel although both increase with temperature; the former, however, increasing faster than the latter. As has been stated previously, the enamels become viscous above 500 or 550°C. At these temperatures we assume that they adapt themselves perfectly to all changes in the stock. Upon cooling there is some temperature at which the enamel becomes rigid and offers resistance to inequalities in contraction. This point has been selected as 500°C, although there is no objection to changing it to a few degrees higher or lower if desired. Accordingly all curves have been set to match at 500°C at which temperature there is an absence of all strains. The deviations of these curves at lower temperatures indicate the corresponding strains to be expected. In most instances the enamels have contracted faster on initial cooling (Enamels 1, 3, 4, 17, 18, 20, 22, 23) and are tending to compress the stock; however, before reaching room temperatures the enamels have slowed up and at normal temperatures all are being compressed by the stock.

Perhaps a more logical method will be to consider the ordinates of the curves referred to contractions rather than expansion. The dotted horizontal lines are arranged to indicate contraction on cooling from the solidification temperature. In figures 3, 4, and 5, this temperature has been taken as 500°C, in the remainder as 450°C. The values at the right of these curves refer to the actual contractions of all specimens on cooling below the fiducial temperature. For example, in figure 3, the contractions on cooling from 500°C to 100°C are as follows: A-21 contracted 0.0048 of

the length at 500 °C and the stock contracted 0.0059 of the length at 500 °C. The difference between the two contractions gives the expected strain at 100 °C, *i. e.*, 0.0011. These values may be used in any system of units, *e. g.*, a 1 meter specimen of A-21 at 500 °C if free to contract will have a length of 0.9952 meter at 100 °C; or a one inch specimen will have a length of 0.9952 inch, and so forth. In practice we may expect a compromise and in reality that the enamel will be compressed below the 0.9952 value due to the greater tendency for contraction of the iron (to a length of 0.9941). Similarly the iron may never reach this lower value but may stop at a higher value due to the restraining effect of the enamel. Table 3 gives the complete assemblage of all values from the series A enamels and various steels and irons. All values in table 3 are expressed as millionths per unit length, per degree C.

Manifestly those enamels most widely separated from the stock at room temperature, A-12, A-21, should have the greater tendency to scale and those more nearly agreeing with stock at this temperature (A-1, A-4, A-20 and A-23) should exhibit a lesser tendency. These conclusions are borne out by the enameled specimens. It should be pointed out that while no enamel matches the stock absolutely, enamels do adhere satisfactorily and that this adhesion is due to the strength and elasticity of the enamel, and to the union of enamel and stock(either chemical or mechanical) and that by properly treating the stock by mechanical means (as will be shown later) it is possible to cause practically any enamel to adhere to any stock, regardless of the inherent strains set up. Unless these strains are later released by annealing as will be explained, the ware should not be expected to stand up under severe treatment.

As previously stated, the empirical formulas of Mayer and Havas are supposed to indicate the expansion of the various batches on the basis of chemical composition. While it is understood that the rate of expansion increases rapidly with temperature (see figures 3, 4, and 5) and that these values do not give complete information, still it was thought desirable to attempt to arrange their values to indicate, if possible, correct expansion at

some one temperature. By comparing the average values for twelve different enamels, it appears that the Mayer and Havas results most nearly indicate expansions for the range from room temperature to 400°C. The original articles, however, show that the values are taken from determinations over the range, room to 100°C. For comparison only, they are arranged near our column, room to 400°C. In some instances the empirical values run above and in other below the experimental. The extreme variation of these is greater than the widest variation for all twelve enamels. It so happens for this set of enamels (excluding the specials 21*a*, 21*b*, 23*a*, 23*b*) that, if we should state that all enamels will have expansions exactly equal to 10.6×10^{-6} (regardless of composition or otherwise) over the range, room temperature to 400°C, then the variations or errors would be less than those obtained by using Mayer and Havas values. A further question is raised as to the wisdom of ever using these values, as is shown by the expansion values observed for enamels 21, 21*a*, 21*b*, and 23, 23*a*, 23*b*. The addition of 5% feldspar to A-21 and 23 gives the 21*a* and 23*a* batch and the addition of 5% more, the 21*b* and 23*b* batch. The feldspar linear coefficient is 8.3×10^{-6} whereas the A-21 enamel computes 9.3×10^{-6} and the A-23 is 11.0×10^{-6}. In each case the addition of 5% feldspar might be expected, according to Havas, to reduce the coefficient and further, the latter enamel (23) should reduce more than the former (21) since its expansion computes 11.0×10^{-6} against 9.3×10^{-6}. Observation will show the values reduced, but in reverse order; number 21 from 10.1 to 9.0 = 1.1 and number 23 from 11.4 to 10.4 = 1.0. The addition of the next 5% feldspar might be expected to give similar (perhaps slightly less) reductions in coefficients; unfortunately it does not, but produces a definite increase in each case. This reduction and later increase may perhaps be explained on some such basis as follows: feldspar may tend to reduce all coefficients toward a value of 8.3×10^{-6} when mixed in batches of material wherein there is an excess of certain other constituent, but when the excess of this certain other constituent is overbalanced by an excess of feldspar the reverse is true. The authors are conscious of the fact that values over a range, room to 100°C, have been applied for a range,

room to 400°C. The range, room to 100°, would have indicated far greater variations and as stated before, the application was made at the point of greatest advantage for the Mayer and Havas values. A further defect in these tables is the fact that they give only a single value for the coefficient whereas the values for all the above specimens increase with increasing temperature. In a later paper, this phase will be treated more fully and an additional reason given, showing why it is impossible to secure relative values from these empirical tables.

We are forced to conclude that there is very little significance to be attached to these formulas of Mayer and Havas and that although they may appear to give results in some cases, there is always the uncertainty of knowing which cases are typical and which are exceptional.

The following conclusions may be drawn from this work:

(1) The coefficients of expansion and contraction are very nearly the same within the temperatures given for the various irons and steels used in this work. Therefore, the variations in fish scaling as evidenced in various steels can not be due to variations in the expansion and contraction of the various steels.

(2) Expansion of steel is greater than that of enamels by 3 to 40 per cent.

(3) The various constituents of the enamel have varying effects on the coefficient of expansion of the enamel.

(4) The values for the coefficients of the enamels between room temperatures and 200°C run from 20 to 40 per cent lower than those for steel.

(5) The coefficient of the enamels increases very rapidly above 200°C.

(6) The coefficient values computed from the Mayer and Havas' table are not accurate. Further, this method gives only a single value whereas it is evident that the coefficient is not constant for the various temperatures.

(7) If held at a constant temperature, between 200 and 300°C the enamels show shrinkage.

Effect of Annealing Enamels

Assuming then that fish scaling is due to the difference in the contractions of the steel and enamel and also bearing in mind further that enamels show shrinkage on slow cooling, annealing or slower cooling of the enameled ware should decrease or even eliminate fish scaling.

A study was made on small plates and stamped bowls coated with enamels A-21 and 23, half of the pieces being cooled normally and the other half placed in an annealing furnace at 500 °C and allowed to cool slowly in approximately four hours to room temperature. It was assumed that this method would allow the enamel to shrink and more nearly match the steel coefficient. A further advantage would be that it would allow the steel to cool and contract at the same time that the enamel contracts, whereas, if allowed to cool suddenly, the protected steel will be hotter than the exposed enamel, and after the enamel becomes rigid will have a longer range of temperature to travel with a larger coefficient, thus intensifying the strain between enamel and steel.

It was clearly demonstrated that annealing of the enameled ware eliminated fish scaling and that the normal air-cooled ware did fish scale, especially with the high boric oxide enamel A-21, which has a low coefficient. The annealed ware has been examined some eight months following the test and there are no indications of scale while the normal pieces scaled within 24 hours following firing.

This study is of value from two viewpoints. First, it demonstrates clearly the value of the coefficient of contraction theory, and secondly, while annealing may be objected to commercially because of the extra cost it entails under present conditions, it points to a decided advantage in the use of continuous enameling furnaces of a tunnel type where provision will undoubtedly be made for cooling the ware slowly as it emerges from the firing zone.

Chemical Compositions of Steels and Irons

When it was shown by thermal expansion studies of the steel and iron stock that many variations in their enameling properties could not be laid to variations in the coefficients of expansion,

it was deemed advisable to make a study of the chemical constituents most likely to affect the enameling qualities. The compositions of the various stocks were as follows:

Table 4—Analyses of Various Enameling Stocks

Stock	Results of analyses in per cent C	Mn	P	Si	S	Cu	Results in enameling
Steel C*...	0.08	0.37	0.020	0.001	0.070	0.022	No fish scaling
Steel D**..	0.066	0.34	0.011	0.002	0.052	0.033	No fish scaling
Iron A.....	0.014	0.009	0.006	0.005	0.025	0.056	Some scaling
Steel E....	0.060	0.36	0.020	0.030	0.056	0.082	Considerable scaling
Steel B....	0.055	0.33	0.008	0.002	0.026	0.270	Badly scaled

* C, hard cold rolled strip steel

** D, dead soft cold rolled strip steel

A review of these analyses and enameling results seemed to bring out very decidedly the fact that fish scaling was intimately related to the copper content of the steel or iron used as the base for the enamel. However, these stocks were comparatively low in copper with the exception of Steel B and it was, therefore, decided to experiment on other enameling steels which would be typical of those containing higher contents of copper. The tests were, therefore, continued on enameling steels of the following composition:

Table 5—Analyses of Steels

Stock	Gauge	Results of analyses in per cent C	Mn	P	Si	S	Cu	Results in enameling
A-A Open hearth....	20	0.075	0.41	0.015	0.010	0.040	0.132	Good
A-B Open hearth....	16	0.075	0.40	0.014	0.010	0.039	0.136	Poor
A-C Open hearth....	24	0.065	0.37	0.035	0.010	0.042	0.148	Fair
A-D Open hearth....	20	0.120	0.34	0.075	0.010	0.041	0.192	Bad
A-E Bessemer.......	20	0.090	0.35	0.080	0.009	0.028	0.160	Fair

These steels were enameled, in the regular method outlined, with Enamels A-21 and 23. It was soon noted that while the gauge has some effect on fish scaling, the heavier gauge steel apparently showing most scale, there was no definite increase of scale with increase in the copper content of the steels. The series was hardly systematic enough, however, to give conclusive proof so an attempt was made to procure a series of steels and irons with increasing copper content from small to large amounts. This resulted in a study on the stock of the following chemical composition:

Table 6—Analyses of Iron Sheets—Copper Series

No.	S	P	C	Mn	Cu	Enameling results
2651	0.017	0.005	0.010	0.012	0.018	Many scales
2636	0.026	0.006	0.014	0.015	0.060	Very few fine scales
2641	0.025	0.008	0.012	0.018	0.090	Few fine scales
2637	0.025	0.006	0.012	0.018	0.190	Few scales
2640	0.024	0.010	0.010	0.018	0.263	Many scales

Table 7—Analyses of Steel Sheets—Copper Series

No.	S	P	C	Mn	Cu	Enameling results
2638	0.029	0.008	0.11	0.410	0.072	Large number of fine scales
2642	0.020	0.011	0.08	0.358	0.094	Large number of fine scales
2643	0.030	0.010	0.11	0.408	0.136	Many large scales
2639	0.020	0.010	0.09	0.388	0.316	Many large scales

It was soon made apparent that fish scaling was not directly related to copper content and that the results of the systematic study did not bear out the earlier conclusions drawn in this connection for there was still evident widely differing results in the amount of fish scaling on the various steels.

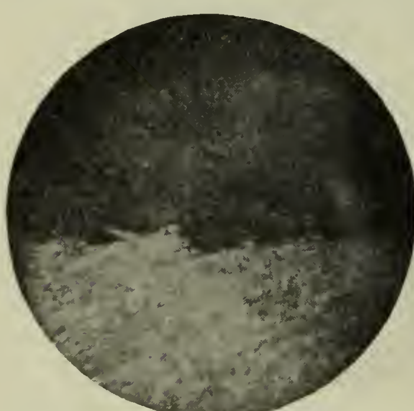
It is sufficient to state that variations in enameling results as regards fish scaling do not appear to be due to the chemical composition of the stock within the ranges studied (and these steels and irons all fall within the limits prescribed for enameling stocks) but rather to their mechanical treatment as will be shown later in this work.

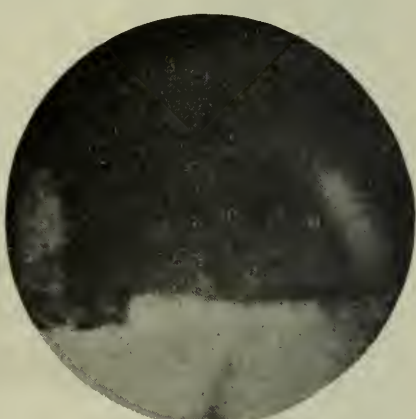
Mechanical Treatment of Enameling Stock

While the foregoing results show that fish scaling may be prevented by selecting an enamel of proper expansivity, at the same time they indicate that other factors have effects which can not be ignored. For example, Enamel A-21 adheres to Steel C but does not adhere to Iron A nor A-B and D Steels. Enamel A-23 gives very little scaling with any of the stocks; one reason, at least, being the nearer match in expansion of Enamel A-23. Now considering expansivity only we should conclude that if Enamel A-21 will adhere to Steel C then it should likewise adhere to Iron A which has practically the same expansivity as Steel C.

The other factors which must be considered to account for the numerous failures of Enamel A-21 are lack of ability to stand up under compressive stress or poor union of enamel and stock.

In many instances, the failure appears to be due to the brittleness or weakness under compressive stress. The form of the scale itself being of varying thickness from full depth at one part to a sharp edge at the outer part at once suggests a compressional failure. It might appear that the roughness or porosity of the stock was sufficient to allow the enamel to penetrate and interlock (figure 6) and that the scale snapped off the stock from a very small smooth area only (figure 7), but spread as it approached the outer enamel surface, giving the scale a form not greatly dissimilar to those of compressive failure specimens.





FIGS. 6 and 7 from adjacent sections. Same edge of enamel showing in both views.

FIG. 6.—Cross section of fish scale, ×215. Where enamel adhered.

FIG. 7.—Cross section of fish scale, × 215. Where enamel scaled.

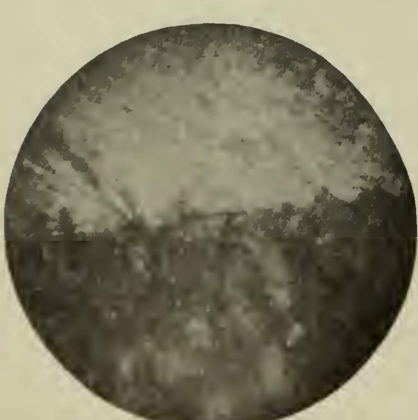


FIG. 8.—Cross section of enamel, ×215. Steel etched away.

FIG. 9.—Cold rolled steel and enamel, ×215.

When larger areas of enamels chip away from the steel, immediately on cooling of the fired ware, failure is undoubtedly due to the lack of union between iron and enamel, and the phenomenon is to be differentiated from fish scaling. Failures of this type have been traced to imperfections in cleaning, pickling, coating of the stock, or similar defects.

All enamelers are familiar with the effects of shapes or patterns in vessels and have also noticed that the sides of a spun vessel do not scale as readily as the untreated bottom surfaces. Tests were made to determine what effects could be attributed to a possible difference in the rate of cooling of protected, and unprotected flat and curved surfaces, by carefully annealing the pans and then enameling. Apparently annealing of the stock had no effect on the fish scaling.

This process of elimination practically forces the theory of mechanical adhesion upon us as the determining factor in this special case. To verify the theory that greater working of the metal was responsible for lack of fish scaling on the sides of drawn and spun vessels, several strips of steel and iron were stretched to 10 per cent elongation. The strips were so clamped that only half of the strip was stressed, so that the comparative effects on fish scaling could be determined under exactly the same conditions.

The plates were cleaned and pickled in the regular way and Enamel A-21 was applied, the latter being typical of an enamel prone to fish scale. It was found in every case that the stressed portion was absolutely free of scale while the normal portion fish scaled, the line of demarcation between the two portions being very sharp in this respect. This effect is unquestionably due to the mechanical treatment of the iron. Expansion tests of both stretched and cold rolled specimens of steel and iron are recorded in table 3 (see Steel C, elongated, Iron A, elongated, and Steel C, hard), from which we see that this treatment has not changed the rate of expansion appreciably.

In casting about for some true explanation of this variation in properties of the steels, use was made of the microscope in studying the surfaces of the metal since it was believed that the

cause for variations would lie in the variations of surfaces. It was noted in these latter studies that the surfaces of Steels C and D (which steels had never developed scaling) were very smooth and regular in structure. It was presumed that the fact that these steels were cold rolled had possibly some effect on their enameling properties and samples of the various steels were given a cold rolling that decreased their thickness by about 0.015 of an inch, and at the same time polished the surface. These steel specimens when enameled gave perfect results and no fish scaling developed.

The results with cold rolling of iron were, however, not as promising. Although the development of scale was materially decreased on the treated iron, there was not the complete elimination of scale which it had hoped would result. It is evident that there is some difference in the effect of cold rolling on steels and on irons which must be explained.

It might be assumed that cold rolling had carried the metal beyond its elastic limits and had introduced certain permanent molecular changes in the metal beneficial from an enameling standpoint. That this is unlikely is shown by the fact that the same results were obtained in enameling regardless of whether the plates had been annealed or simply cleaned in a caustic solution following cold rolling and previous to pickling for enameling purposes.

Further, cold rolled specimens tested in the expansivity furnaces and therefore heated over a period of about 20 hours up to 625°C, at which temperature they were held constant for about two hours and then cooled slowly to room temperatures, behaved exactly as the normal rolled stock.

In mechanically treating the metal, either changes are produced in the surface which permit the enamel to combine with the material chemically or mechanically, or the elastic properties of the stock are so modified that the enamel is no longer crushed in cooling. Doubtless all factors play a salutary part. However this may be, the answer or solution by this method is the same regardless of the theory and is to treat mechanically the stock by stretching, cold rolling, spinning, shaping, or other means whereby all parts of the article are given the equivalent of the above.

In the preliminary microscopic studies of these mechanically treated samples, the ordinary methods were resorted to, that is, examination up to 100 magnifications of cross sections and surfaces. These magnifications proved unsatisfactory.

It was therefore decided to make some studies of the stocks at various magnifications from 200 to 2,000 diameters. On many specimens there is apparent under these magnifications a result of rolling or stretching which may account for its beneficial effect on the enameling properties and which may also account for the limited effect noted in the iron stock.

There has been noted in the case of some of the enameled cold rolled steels a rolling over of the tops of the peaks on the surface of the metal into the minute cavities on the surface in the direction of rolling, especially when examined under the high magnifications and perpendicular to the surface. The enamel, in melting, apparently flows back under these overhanging projections of metal and thus retains its grip on the latter in spite of the strain under which the enamel is compressed, because of the difference in expansion. Attempts are being made to reproduce such a structure artificially and in an exaggerated condition. The preliminary results of enameling such stocks are very encouraging.

In the case of the cold rolled iron, this broken cross section is not present to such marked degree. The surface has a more regular arrangement somewhat similar to that of normal steel. This is undoubtedly due to the greater ductility of the iron allowing the excess metal to be rolled down and united in the cavities, thus tending to nullify the beneficial effects of cold rolling noted in the case of the steels. In the stretched iron and steel, we should expect numerous cavities to be formed or opened up into which the enamel penetrates, which would account for the reduced fish scaling in the stressed iron and steel.

This broken structure was visible at 100 magnifications on the earlier stretched samples of steels and irons but, since the cold rolled steels C and D, at the same magnification, gave a very smooth appearance of surface, the value of the findings was consequently discounted at that time.

The microscopic studies of some sections of enameled iron and steel are shown in figures 6–9. Photographs of a specimen of steel partially cold rolled and enameled are shown in figure 11, while figure 10 shows a specimen of partially stressed steel which has

FIG. 10.—One-half of a steel strip stressed and enameled. Left half (N), normal; right half (S), stressed.

FIG. 11.—Strip, cold rolled and enameled. Left half (N), normal; right half (CR), cold rolled.

been enameled. In these there is apparent the sharp line of demarcation between the normal and the mechanically treated sections. The greater part of the scaling on the normal ends developed within 24 hours after enameling and these specimens were enameled about eight months previous to photographing. In the stressed section, a single scale is shown in the portion receiving the least stressing, since the specimen as photographed is one-half of the strip which was originally stretched.

Part II. Ground Coat Enamels

The second part of this investigation has been devoted to the study of ground coats in order to determine whether the general conclusions drawn from the study of gray ware would apply to three coat enamels.

An average composition was selected from the compositions of three commercial enamels, having various degrees of refractoriness and working properties but all giving good commercial ware. They are as follows in melted weights:

	A	B	C
Boric oxide	13.5	14.0	18.1
Feldspar	27.5	35.6	43.0
Quartz	34.7	25.4	21.6
Sodium oxide	11.6	15.8	11.6
Fluorspar	6.1	7.6	2.9
Manganese oxide	4.9	1.3	1.4
Nickel oxide	1.2	....	1.0
Cobalt oxide	0.5	0.3	0.4
	100.0	100.0	100.0

The average enamel selected for the work was as follows:

Constant	
Feldspar	27
Quartz	21
Boric oxide	12
Sodium oxide	10
Fluorspar	0
Cryolite	0
Cobalt oxide	0.5
Manganese dioxide	1.5
	72.0
Variable	
Refractories	14.0
Fluxes	14.0
Total	100.0

With this composition as a basis the following three series shown in table 8 were outlined, an attempt being made to show the effect of varying the refractories as well as the fluxes as had been done in the study of the gray ware enamels. Ground coats H-1 to H-7 comprise a series with high content of feldspar showing variations in the fluxes. Group H-8 to 14 is a high quartz series and H-15 to 21 is a mean between the high quartz and high feldspar with similar variations in fluxes. The batch compositions are shown in table 9.

These ground coats, weighed in 4.5 lb. batches, were mixed thoroughly and then melted in crucibles in a crucible furnace. The time varied with the fusibility of the frit but averaged from 45 to 50 minutes. The frit in each case was chilled in water and then ground in porcelain ball mills with the following additions:

Frit........................	1200 gms.
Johnson Porter clay.........	72 gms.
Borax (in solution)..........	18 gms.
Water.....................	500 cc.

The time required for grinding averaged 12 hours but in this case it appeared that the time for grinding depended somewhat on the composition, the more fusible enamels requiring less time.

TABLE 8—PERCENTAGE COMPOSITION OF GROUND COAT FRITS

Constant part ingredients	Feldspar	Quartz	B_2O_3	Na_2O	CaF_2	Cryolite	Ox. of cobalt	Ox. of manganese
Constant part % ingredients melted	27	21	12	10	0	0	0.5	1.5
No. of ground	Variable melted parts added to above constant portion							
H-1	14	..	7	..	7	..		
H-2	14	..	..	7	7	..		
H-3	14	..	..	..	7 + 7	..		
H-4	14	..	..	..	7	7		
H-5	14	..	7	..	..	7		
H-6	14	..	..	7	..	7		
H-7	14	..	..	..	..	7 + 7		
H-8	..	14	7	..	7	..		
H-9	..	14	..	7	7	..		
H-10	..	14	..	..	7 + 7	..		
H-11	..	14	..	..	7	7	Constant	Constant
H-12	..	14	7	..	..	7		
H-13	..	14	..	7	..	7		
H-14	..	14	..	..	..	7 + 7		
H-15	7	7	7	..	7	..		
H-16	7	7	..	7	7	..		
H-17	7	7	..	..	7 + 7	..		
H-18	7	7	..	..	7	7		
H-19	7	7	7	..	..	7		
H-20	7	7	..	7	..	7		
H-21	7	7	..	..	..	7 + 7		

Table 9—Batch Composition of Ground Coats for 100 Parts Melted

Constant portion ingredients	Feldspar	Quartz	Borax	Boric Acid	Soda Ash	Sodium Nitrate	Fluor-spar	Cryolite	Cobalt Oxide	Manganese Oxide
Batch weights constant portion	27	21	32.7	——	5.0	4.9	——	——	0.5	1.5
No. of ground	Batch weight of variable parts added to above constant part									
H-1	14	. .	. .	12.4	. .		7	. .		
H-2	14	. .	. .	. . . .	12		7	. .		
H-3	14	. .	. .	. . . .	. .		14	. .		
H-4	14	. .	. .	. . . .	. .		7	7		
H-5	14	. .	. .	12.4	. .		. .	7		
H-6	14	. .	. .	. . . .	12		. .	7		
H-7	14	. .	. .	. . . .	. .		. .	14		
H-8	. .	14	. .	12.4	. .		7	. .		
H-9	. .	14	. .	. . . .	12		7	. .		
H-10	. .	14	. .	. . . .	. .		14	. .		
H-11	. .	14	. .	. . . .	. .	Constant	7	7	Constant	Constant
H-12	. .	14	. .	12.4	. .		. .	7		
H-13	. .	14	. .	. . . .	12		. .	7		
H-14	. .	14	. .	. . . .	. .		. .	14		
H-15	7	7	. .	12.4	. .		7	. .		
H-16	7	7	. .	. . . .	12		7	. .		
H-17	7	7	. .	. . . .	. .		14	. .		
H-18	7	7	. .	. . . .	. .		7	7		
H-19	7	7	. .	12.4	. .		. .	7		
H-20	7	7	. .	. . . .	12		. .	7		
H-21	7	7	. .	. . . .	. .		. .	14		

These were applied to a number of steels, the sample plates being 2 × 3 inches and of 16, 20 and 24 gauge. The steel was prepared by cleaning in an alkaline bath and pickling in hydrochloric acid. The plates were then rinsed in water and the remaining acid neutralized in a weak soda-ash bath.

Enamels were applied by dipping, additional borax being used as a flotation medium when necessary.

In order to obtain the effect of various temperatures on fish scaling, each of the ground coats were fired on six plates according to the following schedule:

Degrees C	Minutes
800	$2^1/_2$
850	$1^3/_4$
900	$1^1/_4$

Firing according to this schedule gave to all appearances, correctly fired enamels. Half of these plates were then coated with a standard white enamel of the following composition:

Frit		Mill	
Borax	500	Frit	100
Feldspar	640	Clay	5
Quartz	360	Tin oxide	7
Soda ash	80	Magnesia	$^1/_4$
Cryolite	240	Water	50
Soda nitre	60		
Antimony oxide	40		
Fluorspar	80		
Total	2000		

The general results on the ground coat enamels are in general accord with those of the gray ware studies. For example, we find in a study of the data that the enamel constituents arrange themselves in the same order as affecting fish scaling, that is, cryolite is a superior flux to fluorspar, boric acid is an exceedingly poor flux from the standpoint of fish scaling, and soda and cryolite are much alike in their beneficial effects. It is to be noted further in this work that feldspar is apparently superior to flint.

Of the 21 enamels only one, H-6, has not developed fish scaling under any condition. This approaches very closely a type of commercial ground coat except that cryolite replaces the usual amount of fluorspar present in ground coats. It is to be noted further that the corresponding enamels in the quartz as well as in the medium-quartz medium-feldspar series (H-13 and H-20), are the best in these respective series and approach the excellent qualities of H-6. Boric oxide as in the case of the gray ware enamels is harmful from the standpoint of fish scaling. It is to be noted that better results are obtained with ground coats H-1 to 7, followed in order by H-15 to 21 and then H-8 to 14. This is undoubtedly due to the fact that the first group is highest in feldspar which we would expect to give tougher enamels in the range of compositions listed and is further evidence that the strength of the enamel is a factor in the tendency to fish scale.

The results of the expansivity studies confirm the conclusions from similar studies of the gray ware enamels and give further proof of the accuracy of our basic reason for the phenomenon of fish scaling. The coefficient values shown in tables 10 and the expansivity charts showing cooling curves for Enamels H-1 to 14, (figures 12 and 13) as compared with and matched to steel at 450 °C, make this evident. It will be recalled that the gray ware enamels were matched with the stock at 500 °C on the basis of tests

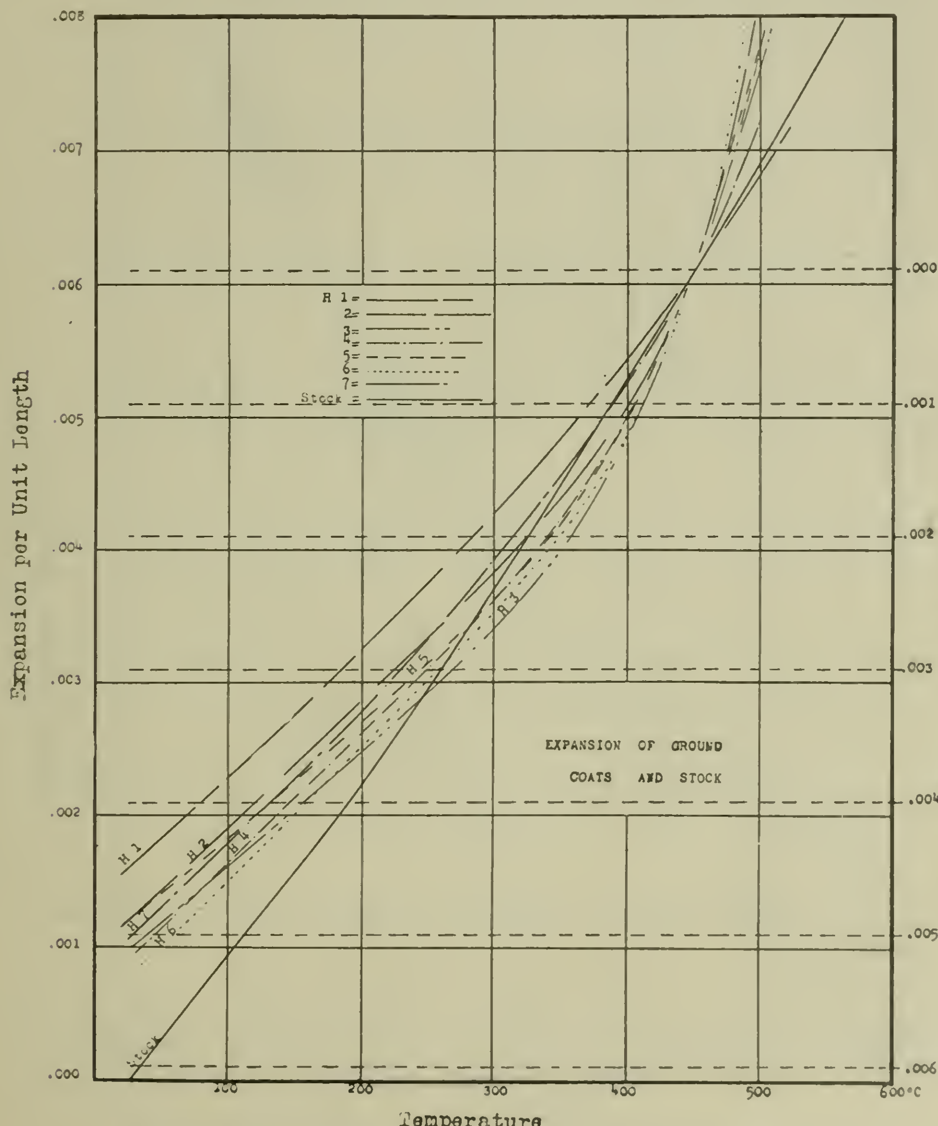


FIG. 12.—Expansion of ground coats H-1 to 18 and stock.

which showed that the gray ware enamels became viscous at approximately 550°C. It was found, however, that the ground coats softened at about 500°C and it was therefore necessary to lower the assumed temperature for initial rigidity of enamel and to fit the stock and grounds at 450°C. The following general conclusions can be drawn from the expansivity studies:

(1) Feldspar, replacing corresponding amounts of flint as a refractory, gives higher values for the expansion coefficient than the flint.

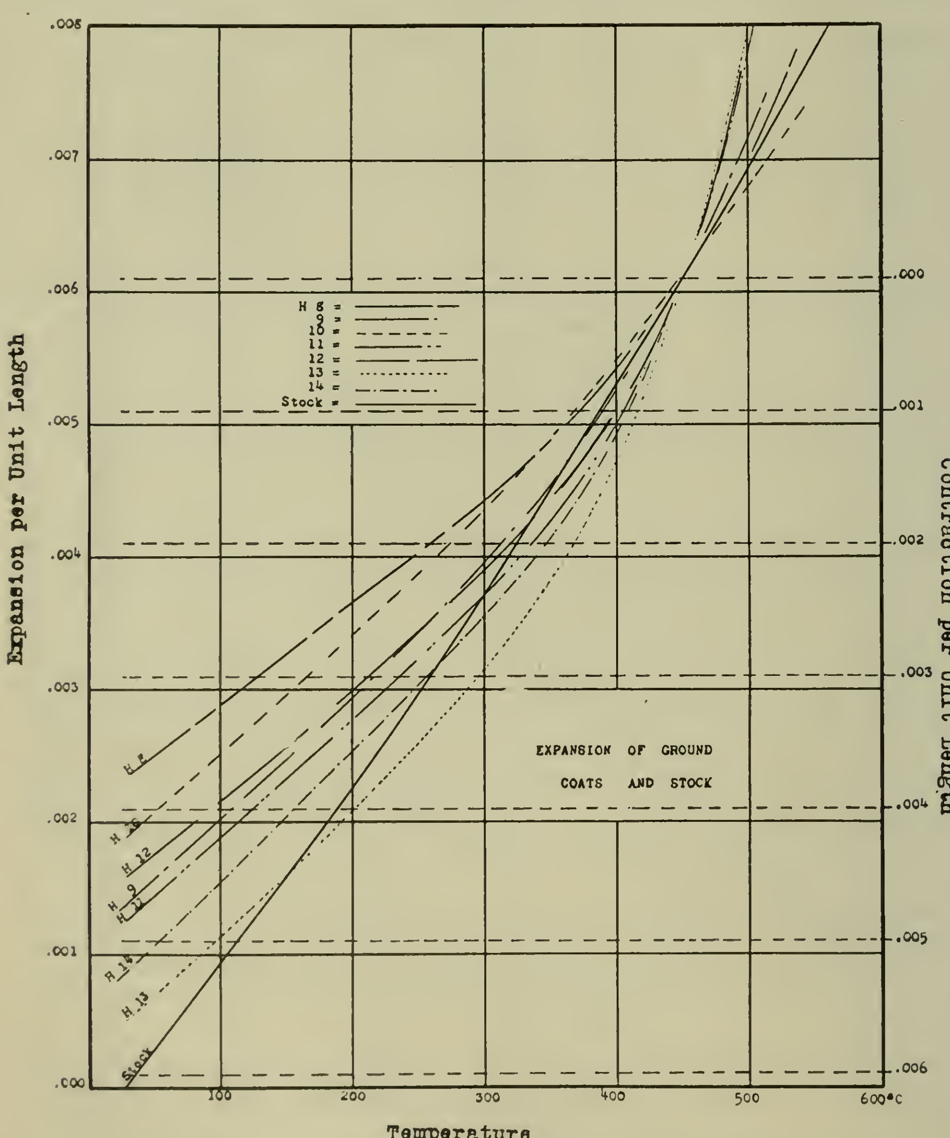


Fig. 13.—Expansion of ground coats H-8 to 14 and stock.

(2) Cryolite gives higher values on the average than fluorspar.

(3) Boric acid gives the lowest values.

(4) Sodium oxide and cryolite combinations give the highest values followed by that for cryolite alone.

The fusion points of these ground coats place the various fluxes in their same relative order as regards fluxing value (figure 14), as observed for the gray ware enamels. The cone method of determining fusion points was not applicable to the ground coats

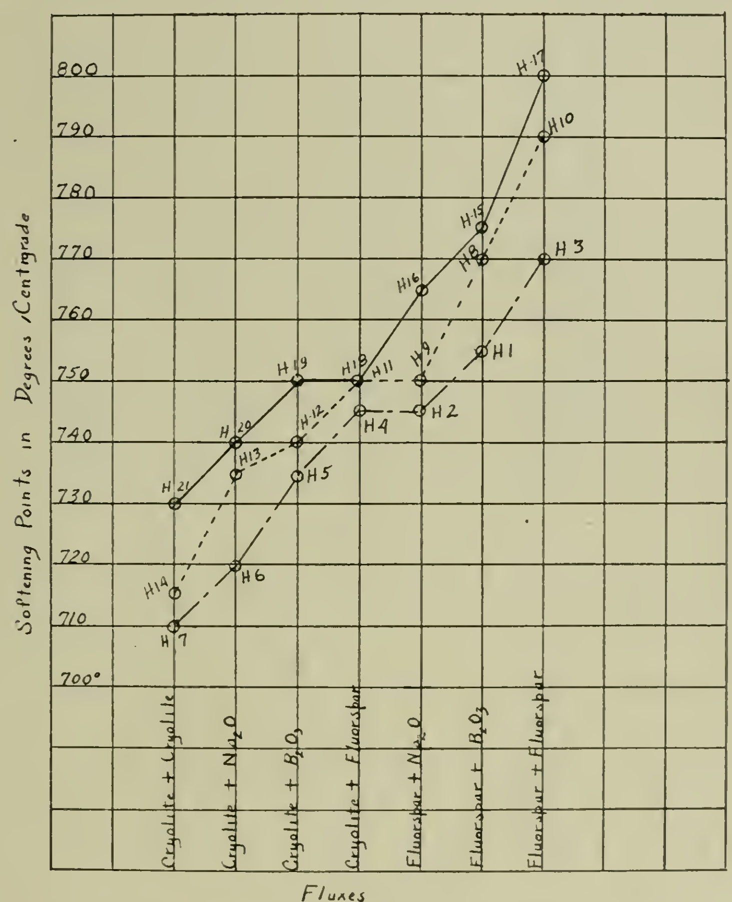


FIG. 14.—Relative fusibilities of ground coats.

as the fluxes separating out from the refractories tended to give erratic results. These softening points were, therefore, determined by placing pats of enamel on a plate and heating for two minutes at various temperatures.

The results of tests of shape of ware, annealing of enameled ware, treating of the steel, and so forth, have all corroborated the results obtained with gray ware enamels so it would appear that the conclusions can be applied generally to sheet steel enamels.

TABLE 10—COEFFICIENTS OF EXPANSION $\times 10^6$. GROUND COAT ENAMELS AND STEELS

Ground	Room to 200°C	Room to 400°C	Room to 450°C
H-1	9.2	10.3	10.5
H-2	9.4	10.3	11.5
H-3	8.4	10.4	12.1
H-4	9.7	10.9	12.3
H-5	8.3	10.0	11.4
H-6	9.7	10.9	12.6
H-7	9.8	11.2	12.5
H-8	7.5	8.4	8.9
H-9	8.9	10.3	11.2
H-10	8.8	9.5	10.0
H-11	8.8	10.3	11.5
H-12	8.2	9.4	10.7
H-13	9.1	11.5	13.3
H-14	9.5	10.8	12.3
Av. Steel	12.8	14.0	14.2

CORDS AND SURFACE-MARKINGS IN GLASSWARE[1]

By F. E. Wright

ABSTRACT

In the manufacture of glassware it is important to distinguish between surface-markings and cords, both of which are serious defects and detrimental to quality. To do this immerse the piece of glass under test in a liquid of the same refringence and sight through liquid and glass toward a distant light. Under these conditions surface-markings disappear altogether. Cords, on the other hand, stand out more distinctly than before.

The relative refringence of a cord compared with that of the adjacent glass can also be determined at the same time. For ordinary crown glasses monochlorbenzene is suggested as an immersion liquid. To lower its refractive index add benzene; to raise it add carbon bisulfide or monochlornaphthalene.

Cords are unwelcome guests in glassware because they appear even to the casual observer as flaws and blemishes in otherwise clear glass. Glass intended for the better grades of jars and tumblers, for chemical ware, electric lamp bulbs, lamp chimneys, and the like should be free from defects of this sort. To the manufacturer their presence may mean discard of the finished article and financial loss; they signify to him a fault in manufacture, such as inadequate mixing of the batch, pot or tank-wall solution, or improper furnace control. They cannot be removed by any subsequent manufacturing operation after the glass has left the melting furnace. Cords are the trails left by currents of material of slightly different chemical composition within the molten glass. To the eye they appear like cords, strings, threads, ribbons, veins, or streaks of colorless material suspended in the glass; hence the variety of names used to describe the different types of striae.

Optical effects similar to those produced by striae may also result from the presence of faint markings or irregularities on the surfaces of the finished glass article. Under certain conditions these markings may become sufficiently serious to cause rejection of the finished article.

[1] Received April 11, 1921.

It is important for the factory foreman to distinguish between cords and surface-markings so that in a given case he can diagnose the trouble correctly and then apply the proper remedy. The purpose of this note is to describe simple methods for the diagnosis of these defects in glassware; in particular to distinguish between surface-markings and striae or cords; and, in the case of cords, to ascertain their refringence relative to that of the enclosing glass and thus to ascertain their probable composition.

In the manufacture of glassware the ordinary factory procedure is to draw from the pool of molten glass within the melting furnace a sufficient quantity of glass on the end of a blow-iron or punty, and, while the glass mass is still hot, to blow, press, or mould it into the desired shape. If on removal from the furnace the glass is too cold and too viscous, the corrugations and indentations on the surface of the ball of molten glass on the end of the blow-iron are not entirely effaced by flow, with the result that during the blowing or pressing operations these surface irregularities persist and are drawn out into fine thread and ribbon-like surface-markings which may resemble cords. They are less serious from a glass maker's standpoint than are cords because they can ordinarily be eliminated by simple means.

The obvious remedy for surface-markings is to increase the liquidity of the melt either by raising its temperature at the point where it is withdrawn from the furnace or by changing the composition of the batch so that at the given temperature the glass melt is sufficiently mobile.

Another source of trouble may be corrosion of the tank or pot walls whereby alumina is introduced as a silicate into the melt, thereby changing its viscosity locally; under these conditions cords may be expected in the glass in addition to surface-markings. The process of assimilation of clay material dissolved from the walls of the container is necessarily slow and the chances are favorable that strings, threads, and ribbons of the dissolved material are carried by convection or other currents into the body of the molten glass mass, and may persist as streaks of slightly different composition for long periods of time. Striae mark the stream lines or paths taken by some of these currents within the pool of molten glass. In each case it is desirable to ascertain the cause

of the local inhomogeneity in composition and to trace it back to its source. The following relations are significant in this connection. Observation has proved that the composition of the surface, to a depth of half a millimeter or more, of a pool of molten glass is slightly different from that of the main body of the melt. This is true even in an optical glass melt which is stirred vigorously for many hours. This surface film is higher in silica and lower in alkalies than the underlying glass; its formation is due to selective volatilization, especially of the alkalies, from the liquid glass. Its refractive index is lower than that of the subjacent glass; it is also generally more viscous because of its higher silica content and if carried down into the body of the melt gives rise to striae which, if heavy, are objectionable. In case alumina is introduced from the walls of the container, streaks of glass richer in alumina are to be expected and these, in ordinary glasses, may have a higher or a lower refractive index than the adjacent glass. If the refractive index of a cord is found to be higher than that of the glass surrounding it, the source of trouble may be corrosion of the container walls (pot solution) or an original difference in composition not entirely eliminated by diffusion within the pool of molten glass.

In a large pool or pot of molten glass the conditions are such that homogeneity throughout the mass is not and probably can not be attained. This means that, because of currents and differences of viscosity, some cords and striae are ever present within the metal and in process of further attenuation and assimilation. It is the task of the glass maker to keep these striae within bounds so that in the finished article they are fine and scarcely noticeable except on close inspection. The more definite facts he can obtain regarding cords and surface markings in any given case the better is he able to infer the real source of trouble.

The reason why cords and striae are visible in glass is because their index of refraction is different from that of the surrounding glass. If it were possible to ascertain the refractive index of a given cord or even its refringence relative to that of the glass in which it is embedded, a series of simple experiments with any given glass composition would enable the glass maker to determine the effects which changes in the composition of the glass produce on

the refringence relations. Having thus ascertained, for example, the changes produced by the addition of clay (pot-solution) and compared its effect with that produced by an excess of silica or a decrease in alkalies, he is able to state with some assurance in a given case whether pot-solution or volatilization is the cause of the cords.

The methods for distinguishing surface markings from cords are fortunately easy of application and do not require elaborate apparatus; furthermore the refringence of a cord relative to that of the surrounding glass can be readily ascertained. These methods will now be described briefly.

The effect of irregularities in the surface of glass on rays of light is to deflect them from their straight course. The more pronounced the markings, the greater the degree of deflection and the more readily are the markings seen. Their effect on rays of light is similar to that exerted by a hand lens or a burning glass, namely, to refract and diffract the light. The amount of deflection produced by a given lens or surface corrugation depends on the difference in refringence between the glass and its surrounding medium. It is possible to choose a liquid which for a given color of light has exactly the same refractivity as the glass; in this case the rays of light pass through the glass surface into the liquid without any perceptible deviation; the surface markings disappear altogether and can not be seen even under the most favorable conditions of observation. Cords and striae, on the other hand, are completely surrounded by glass and the liquid does not come into contact with them; under these conditions they do not disappear when the glass is immersed in a liquid of the same refractive index but become more conspicuous because all surface irregularities are virtually suppressed and these tend ordinarily to obscure or veil striae.

The refractive index of ordinary crown glasses for yellow light ranges between 1.515 and 1.525, and for these a satisfactory immersion liquid of about the same refractive index is mono chlorbenzene.[1] To determine whether the cord or striae-like mark-

[1] Obtainable from any dealer in chemical supplies. In a recent list from the Eastman Kodak Company the price for 5 kilograms of monochlorbenzene is stated to be $3.

ings exhibited by a piece of glassware are actually cords or surface markings the article is viewed first in air and then while immersed in a tank of monochlorbenzene. A suitable tank can be made by bending a flat piece of heavy metal (iron, brass, or copper) into a flat-bottomed U-shape; this forms the bottom and two ends of the tanks; the two sides are of plate glass cemented to the metal with a mixture either of Le Page's glue and plaster of paris or of lime and zinc oxides in sodium silicate (water glass). A square fish aquarium serves the purpose well, provided its sides are of plate glass. For these experiments a distant source of light (electric lamp bulb ten or more feet distant) is used (figure 1).

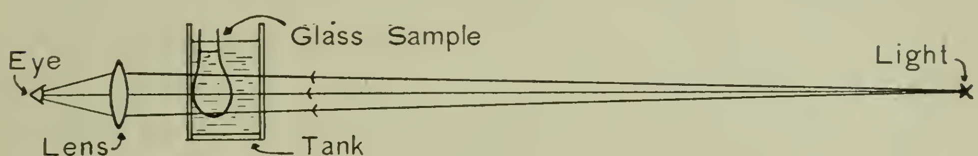


FIG. 1.—Optical arrangement suitable for distinguishing between surface-markings and cords. The glass sample is immersed in a liquid having the same refractive index and contained in a tank with parallel glass sides. The immersed sample may be viewed against a distant light with or without the aid of a hand lens.

Surface markings on a piece of glass examined under these conditions of immersion disappear altogether, whereas striae and cords stand out more clearly than ever. It may be noted that in every case it is necessary to have all surfaces of the article under examination in contact with the liquid in order to avoid total reflection and other disturbing phenomena. This means that lamp bulbs, tumblers, and other hollow articles should be filled with the liquid as well as immersed in it.

A simple test to ascertain if the liquid and the immersed piece of glass have the same refringence is to sight through the immersion tank toward the distant light and to note that the light does not shift its position when the immersed piece of glass is placed in the line of sight. If the light does shift, the refringence of the liquid is either too high or too low. Let us suppose the piece of glass is wedge shaped. Move it so that the thin edge crosses the line of sight first; then if the light is seen to shift *toward* the glass block, the liquid has a lower refractive index. Thus if the

block with its sharp edge to the left, is moved across the line of sight from right to left and the source of light is thereby deflected toward the right, the refractive index of the liquid is too low, and vice versa. When the refractive index of the liquid and glass are the same for yellow light, red and blue color fringes appear on opposite sides of the glass block. The refractive index of the immersion liquid can be lowered by the addition of benzol or some still lower refracting liquid; it can be raised by adding monochlornaphthalene[1] or carbon bisulfide or other strongly refracting liquid.

The immersion test is extremely simple and enables the operator to determine definitely at a glance whether the source of trouble is surface markings or cords. It is a fact of observation that in blown or pressed ware the surface markings are confined chiefly to the exterior surfaces and appear rarely on the inner surfaces.

With the aid of a pocket hand lens or low-power magnifying glass (watch-maker's glass) it is possible at the same time to determine the refringence of a cord relative to that of the adjacent glass. To do this, sight toward the distant light through the magnifying glass and in the direction of the glass article immersed in the tank (figure 1). Move the eye and lens toward or away from the piece of glass until the cords are brought to sharp focus and the fine details can be readily seen. Now draw the eye and lens a short distance back from the position of sharp focus and observe the change in illumination over the cord or striae. In case the cord has a higher refractive index than the glass, the rays of light are convergent and the center of the cord in the new position appears brighter than the adjacent field. The reverse is true for a cord of lower refractive index; also for a cord of higher refractive index when the eye and lens are moved from the position of sharp focus nearer to the cord. In these cases the center of the cord appears darker than the adjacent field.

Under these conditions of observation, diffraction phenomena give rise to series of narrow alternate light and dark bands which at first may be disturbing to the observer; but after a few trials their presence is recognized as inevitable and they do not actually

[1] Made by the Condensite Company of America, Bloomfield, N. J., under the trademark "halowax oil."

interfere seriously with the results. They can be largely eliminated if a different mode of illumination be used, namely, a ground-glass plate, a foot square, not too far distant (several feet), and illuminated from behind by an electric lamp bulb; directly in front of the plate a perforated screen or lattice work is placed. The bars in a distant window may serve the purpose equally well. Under these conditions of oblique or half-shadow illumination, the cords exhibit a one-sided illumination and appear to stand out in relief. In this method a hand lens is not required, but may be used to render details more easily seen. From the relation of the shadow-side of the cord to that of the direction of the incident light the relative refringence of the cord can be readily deduced. For example, let the line of sight be toward the sky or horizon as seen through a distant window. Bring the sample of glass into the line of sight and look at it instead of at the distant window. Note that now the sides of the window are no longer sharp; but there is a gradual transition from light near the center of the window to dark beyond the sides. If a cord in the glass sample falls within the half-shadow on the left of the window and the side of the cord facing the shadow (left side) is brighter than the opposite (right) side, the refringence of the cord is higher than that of the surrounding glass. Because of the variety of shapes of cords, several cords should be tested before a definite conclusion is reached. If surface-markings are present, the sample should be tested while immersed in the proper liquid.

Geophysical Laboratory
Carnegie Institution of Washington
March, 1921

ZIRCONIA CEMENTS[1]

By Mark Sheppard

ABSTRACT

The effect of calcined zirconia on zirconia cement. Seven refractory cements were made having compositions of zirconia 90 per cent and plastic clay 10 per cent. (1) **The shrinkage** was found to be excessive in a cement containing raw zirconia and clay. The addition of 50 per cent or more of calcined zirconia practically eliminated this shrinkage and the cracking which accompanies it. (2) **Strength.** Draw trials showed that the cement became strong at 1200°C and that it was very strong when burned at 1700°C. (3) Load tests on piers at 1500°C showed that joints of these cements did not fail in any manner at this temperature. (4) An industrial test of zirconia cement used as a wash for bungs in a malleable iron furnace showed that the life of a bung was increased about 25 per cent by the use of a zirconia wash.

Introduction

Zirconium and its salts have been used in several industries, although not in large amounts. Pure fused zirconia has a linear coefficient of expansion of 8.4 x 10^{-7} and a fusion point of about 2600°C.[2] The thermal conductivity of zirconia brick is approximately half that of fire-clay brick.[3] It is comparatively inactive in the presence of either acidic or basic materials at high temperatures. These properties have lead many investigators to experiment with zirconia for refractory purposes. Much of this work has been in the production of laboratory ware from zirconia containing at least 99 per cent of ZrO_2. Bricks and cements have also been made from crude zirconia containing from 75 to 80 per cent of ZrO_2.

The great difficulties in the use of zirconia as a refractory have been the excessive shrinkage, the lack of a suitable bonding material and the high cost. The first two apply more particularly to the use of zirconia in electric furnaces at the most extreme temperatures. The cost is of more importance in the case of furnaces which operate at more moderate temperatures.

[1] Received, April 15, 1921.

[2] Average of the determinations of several investigators.

[3] H. C. Meyer, *Chem. Met. Eng.*, **13**, 263 (1915).

The Brazilian deposits of zirconium oxide are so large that zirconia has ceased to be in reality a rare earth—in fact, the cost is low enough to make zirconia an important refractory material. The deposits of zirconium silicate are also large, although very little research work has been done in this field.

The present uses of zirconia as a refractory are in the making of bricks and refractory cements for metallurgical furnaces, and in crucibles and laboratory ware. Zirconia has also been used as an opacifier in enamels, as a resistance body in the Nernst lamp as an incandescent coating for gas mantles, and as a white pigment for paint. Zirconium has been used in alloys with several other metals, the most important of which is ferro-zirconium.

Experimental

A series of refractory cements was made and tested, both in the laboratory and in actual practice, for use either in laying refractory brick or as a protective coating.

Two grades of zirconia were available for this work. Their characteristics are as follows:–

Chemical Analysis

	Crude zirconia	Refined zirconia
ZrO_2	74.04	94.57
SiO_2	17.62	0.20
Fe_2O_3	3.84	2.29
Al_2O_3	3.58	2.20
TiO_2	0.85	0.83
Total	99.93	100.09

The crude zirconia is of the grade commonly imported. Its color is gray or brown, depending on the state of oxidation of the iron. Its specific gravity is 4.83 and its hardness is 5.5 to 6.0. It has considerable burning shrinkage, which increases as the temperature is raised, making it necessary to burn refractories of this material to a temperature as high as that at which they are to be used. The shrinkage[1] at 1400°C. is 9 per cent. With the addition of 7 per cent clay, the shrinkage increases to 12 per cent. To lessen the shrinkage for use in cement, the crude zirconia was calcined at 1450°C. This calcination increased the specific gravity from 4.83 to 5.12.

[1] H. C. Meyer, *loc. cit.*

In the refined zirconia all the silica, together with a part of the iron and alumina, has been removed. The specific gravity is 5.18. It has no shrinkage after it has been burned at 1550°C. and it is much harder than the crude ore.

Since zirconia posesses no plasticity, 10 per cent of ball clay was added to each batch to give better working qualities and to make the cement adhere more firmly.

The analysis of the clay used was:

SiO_2	48.94
Al_2O_3	36.69
Fe_2O_3	?
CaO	0.47
MgO	0.71
Alkalies	11.28
Ignition loss	2.14
Total	100.58

The following series of cements was made up from crude zirconia and clay for the purpose of determining the amount of calcined material needed to prevent excessive shrinkage and the cracking which accompanies it.

1.	Raw crude zirconia	90
	Clay	10
2.	Raw crude zirconia	70
	Calcined crude zirconia	20
	Clay	10
3.	Raw crude zirconia	40
	Calcined crude zirconia	50
	Clay	10
4.	Raw crude zirconia	20
	Calcined zirconia	70
	Clay	10

It was desirable to keep the clay content as low as possible so that the refractoriness of the cement would not be lowered. Ten per cent of clay was found to give a cement of satisfactory strength and consequently it was used throughout.

Three members containing refined zirconia with crude zirconia were added to the series. The compositions were:

5.	Refined zirconia	45
	Raw crude zirconia	45
	Clay	10
6.	Refined zirconia	60
	Raw crude zirconia	30
	Clay	10
7.	Refined zirconia	75
	Raw crude zirconia	15
	Clay	10

These members were added both for the study of elimination of the shrinkage and also with the idea of getting a more refractory cement. The screen analysis of the zirconia was, percent:

Through 20-mesh	100.0
Retained on 40-mesh	40.0
Retained on 60-mesh	18.4
Retained on 80-mesh	8.8
Retained on 100-mesh	13.6
Retained on 150-mesh	2.2
Retained on 200-mesh	6.8
Through 200-mesh	9.7

The clay was screened through 40-mesh.

The cements were mixed with 18 per cent of water to a rather wet mortar, and a coating about 3/16 inch thick was spread on one face of a fire brick. The test specimens were thoroughly dried, heated to 1400°C., and held at that temperature for five hours. Cracks were noticeable in cements No. 1 and No. 2 after being burned. The cracks in No. 1 were apparent after drying, but those in No. 2 were produced in burning. No. 3 cracked slightly but not seriously. In No. 4 the cracking was negligible. No. 5 cracked very slightly and appeared to be about equal to No. 4. Nos. 6 and 7 did not crack at all.

The color was determined entirely by the proportions of crude and refined zirconia. The crude ore imparted to the cement a dark brown color in the presence of 10 per cent of clay, while the color of the refined ore was considerably lighter. Cements No. 1 and No. 2 did not adhere very well because of their high shrinkage, but the remainder of the series adhered excellently.

A pier was made of silica splits with cements, Nos. 3, 4, 5, and 6 used in the joints. The joints were made $^1/_4$ inch in thickness. This pier was tested under a total load of 400 pounds (25 pounds per square inch). The furnace was raised to 1500°C in six hours and held at this temperature for one and one-half hours. At the completion of the test no change of volume, compression, or other sign of failure was noted in the cement.

Further tests showed that these cements possessed rather low dry strengths, but after heating to 1200° C., they were sufficiently strong to withstand furnace conditions. Since a material of this kind would not be applied for service at temperatures below 1300° or 1400°C, a satisfactory bond is assured. Draw trials made at 1700°C had a cold strength similar to that of magnesite brick.

For use up to 1700°C the refined zirconia additions did not improve the cement noticeably. At considerably higher temperatures the refined zirconia cements would undoubtedly be better than those containing crude zirconia.

Industrial Test

A test on zirconia cement No. 5 as a wash for bungs was carried out in a malleable iron melting furnace. It was found that bungs which had their bricks dipped in a thick paste of zirconia cement lasted about 25 per cent longer than bungs washed with the fire clay customarily employed. The following is an excerpt from the report of this test:[1]

"The first test with three bungs was started on November 8, 1920, in our No. 2 melting furnace. The first bung (A) was washed with our own fire clay; the second bung (B) was washed with your zirconia wash; the third bung (C) had its bricks dipped in a thick paste of the zirconia wash. Bungs A and B were liberally washed three times, the bricks being allowed to dry almost completely between washings.

[1] Private communication of C. W. Rodman, to whom the writer wishes to acknowledge his indebtedness for coöperation in supervising the practical test in the malleable iron foundry.

"These bungs were placed next to each other, A being the seventh from the front bridge wall, B the sixth, and C the fifth. The bungs were in the arch which deflects the flame on the bath and in the opinion of the writer, this is the severest service in the furnace. Bung A lasted twenty heats, bung B twenty-two heats, and bung C thirty-one heats. A and B might have lasted one or two heats longer, but were replaced by new ones as a falling bung causes trouble. Bung C, however, after twenty-two heats was removed and placed directly over the front bridge wall, where it was subjected to very severe treatment. We allowed this bung to remain until it fell in, desiring to see just how long it would last.

"Another test of five bungs was started December 1st. Three bungs A, B, and C were dry, no wash being used; D and E had their bricks dipped in zirconia wash. These bungs were placed in the middle of the furnace and in such a position that they did not have to be moved. These bungs were level. A and C lasted twenty-one and twenty-two heats, respectively, E twenty-nine heats and B and D are still in use. The positions of these bungs were as follows: B was in the middle of the furnace; on one side of B, bung D was placed, on the other side, bung E; directly next to D was placed A, and next to E was placed C. From the position we can see the extreme bungs A and C would be subjected to the greatest abrasion during charging, and it was these bungs which failed first. The other three bungs were somewhat protected by these end bungs."

In this test it is noticeable that the bungs which had their bricks dipped in the zirconia cement gave considerably longer service than those in which the cement was merely washed onto the completed bung. This emphasizes an important point in the use of protective washes, *viz.*, that the wash should be applied in a thick coat, preferably about $^3/_8$ of an inch thick, and it should extend back into the joints. A protective wash which is very thin and which has a high thermal conductivity does not protect the brick from vitrification. The latter, as soon as they become dense, show a much greater tendency toward spalling[1] with a consequent loss of the coating of cement.

[1] Howe and Ferguson, THIS JOURNAL, 4, 32 (1921).

Summary

1. Raw zirconia alone cannot be satisfactorily used as a cement because of its high shrinkage.

2. The addition of 50 per cent or more of calcined zirconia produces a strong cement which does not crack in drying or in burning, and which becomes mechanically strong at 1200°C.

3. The addition of 10 per cent of clay does not seriously reduce the refractoriness.

4. The use of zirconia cement as a wash on malleable bungs lengthened their life about 25 per cent.

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THE APPLICATION OF PRODUCER GAS TO PERIODIC MUFFLE KILNS[1]

By F. B. Ortman

ABSTRACT

Specific Installation.—Describes installation of Underwood System to six terra cotta kilns at plant Northwestern Terra Cotta Company.

Conclusions from operating data.—(1) Raw producer gas can be successfully applied to periodic muffle kilns. (2) There is little or no direct fuel economy over direct firing. (3) There is no labor economy unless the installation be large enough to justify mechanical coal and ash handling devices. (4) When interest on investment, depreciation and all other pertinent factors are taken into account, it is not likely that any great economy would be affected on periodic kilns over direct fire methods.

Advantages.—They are: (*a*) Somewhat better control of combustion gases and kiln temperatures. (*b*) Decided saving in kiln repair costs. (*c*) Cleaner and more orderly kiln yard. (*d*) Abatement of smoke nuisance, particularly important in large cities.

Introduction

The use of raw producer gas as a fuel for the burning of periodic muffle kilns is, we believe, a rather uncommon practice. In fact, the only installation of this kind of which the writer has any knowledge, is that put in at the plant of the Northwestern Terra Cotta Company, Chicago, early in 1918. This installation was operated continuously for a period of six or eight months, but has not been operated since that time. It was not discontinued because of its having proven a failure but because of other considerations quite aside from its performance and of no particular interest in this connection.

In the hope that the experience with this installation may be of interest to others the following data, taken from various reports and notes made at the time are presented here.

It should be emphasized at the outset, that the experience with this installation was confined entirely to muffle kilns burning architectural terra cotta, which presents an entirely different problem from an open kiln burning brick, etc.

[1] Received April 2, 1921.

Installation

The installation consisted of two rectangular up-draft brick producers, 9′ x 15′ inside and fired from the top through three of the usual bell-feed hoppers. They were equipped with a water-sealed ash pit, the air and the steam being admitted by means of a steam injector to a tuyere running longitudinally along either side of the producer under the fuel bed.

The gas from each producer emptied into a main underground duct from which it was taken off by underground distributing flues to each of two 18 ft. diameter kilns and three 19 ft. diameter kilns. Each kiln had nine fire boxes equipped with gas burners supplied by The Manufacturer Equipment Company. The kilns were of the usual round, up and down draft, muffle type and were all practically identical in design. The 18-ft. kilns would have a capacity of about thirty-two burned tons and the 19-ft. kilns about forty burned tons.

The air for combustion was supplied at a pressure of about 8 oz. by a small blower fan, and was conducted around the kilns overhead in a 12″ galvanized duct. It was not preheated, being applied at the burners at outside atmospheric temperatures.

Operation

The successful adaptation of producer gas to kilns of the type in question involved the solution of two problems, *viz.*, The Producer Problem and the Kiln Problem.

Producer Problem.—The conditions necessary to maintain, in order to produce a good quality of gas, are perhaps much the same as in any other type of producer installation. The requirements, however, are somewhat different from those of a continuous kiln or other similiar installations, in at least two respects.

First: The gas must constantly be maintained at high quality and burned with as low an excess of air as possible, in order that the volume of combustion gases may be kept at a minimum. Otherwise, the comparatively complicated flue spaces which exist in kilns of this type will become overloaded, and choked, resulting in excessive heat in the combustion chamber and an uneven burn. In the burning of brick or other material in open kilns, it is reported to be of distinct benefit, especially during the water

smoking period, to burn the gas with large volumes of air, since the excess air thus introduced performs the very necessary function of assisting in the rapid removal of the water. In the muffle kiln, however, this excess air performs no such function, the air for water smoking being supplied from other sources quite independent of the combustion gases.

Second: The gas must be fed to the burners primarily by pressure, rather than by suction, as in the case of continuous kilns, for example. This introduces another factor influencing the possible adjustment of the steam and air at the producer, quite apart from the adjustment which might be necessary for producing the best quality of gas. This is particularly in evidence when a kiln is first lighted and before a good stack draft is established.

In order to meet these requirements, therefore, it is necessary that the producer plant be kept at the highest possible state of efficiency. Our experience with the above installation indicated that the following were the essential factors for obtaining this result.

First: Ample capacity, in more than one unit. This is obviously necessary in order that the supply and quality of gas may be maintained under varying loads, and during breaking down and cleaning of fuel beds.

Second: The selection and use of the best possible coal commercially available. Such a coal should be as nearly uniform in size as practical, and not too large. It should also carry a low sulphur and ash content. Probably a washed nut would be the ideal coal, although in some markets, natural coals might be available which would be more economical.

Third: The careful regulation and standardization of operating conditions, such as steam and air supply, amount of coal and frequency of firings, frequency of pokings of fuel bed, breaking down, cleaning, etc. These conditions vary greatly with different coals and can only be adjusted by actual experience on part of the operators. It is important, therefore, that after a suitable coal has been found, every effort be made to insure a steady supply of same, as every change of coal results in at least a temporary drop in the efficiency of the producer.

Kiln Problem.—Being assured of a steady and ample supply of a good quality of producer gas at the burners, it then becomes necessary to burn the same economically and with satisfactory results in the kiln. The first difficulty one would expect to encounter in this respect, *viz.*, the use of cold air for combustion, was satisfactorily solved by the Underwood Burner. This burner, while simple in design, proved efficient, and permitted control of the excess air and flame length somewhat more accurately than is possible by the direct fire method, always assuming, however, that the producer was delivering a good and uniform quality of gas.

Another point observed is the effect on kiln linings, flues, etc. While the operation was not continued a sufficient length of time to supply definite data on this point, it was clearly apparent that the uniformity of fire-box temperatures maintained with the gas firing, greatly reduced the necessary kiln repairs.

Comparative Economy

The economy of this type of installation as compared with direct fired kilns, is of course a very vital point. Careful measurements of fuel consumed, over a sufficiently long period of continuous operation to be reliable, showed us that the actual coal fed into the hoppers of the producer per kiln or per ton of terra cotta burned, was slightly less than the same kilns had been requiring under direct firing. If however, the producers were charged (as they should be) with the coal required to furnish steam and power necessary for operation, then the relative economy was slightly in favor of direct firing.

On the installation in question there was no saving in labor cost. Possibly a larger installation which would justify mechanical coal and ash handling devices would show some saving in this respect.

Quality of Ware Produced

There was no appreciable difference observed in the quality of ware produced, it being equal in every respect to that produced under direct firing.

Glendale, Calif.

CONTINUOUS TUNNEL KILNS AT THE PLANT OF MOUNT CLEMENS POTTERY COMPANY[1,2]

By C. B. Harrop

ABSTRACT

These two direct-fired kilns (bisque and glost) are placed end to end in a specially constructed kiln building 825 feet long. Both kilns are fired with soft coal, hand stoked. Three motors are required, aggregating $8^1/_4$ horsepower on each kiln. Hydraulic car pushers are employed. A pressure of 8100 lbs. is required to move the 44 cars thru the bisque kiln. The bisque kiln cars hold 278 dozen ware each and at a 55-minute car schedule, deliver over 7200 dozen ware per 24 hours at a fuel saving of more than 85% over the former periodic kiln operating at this plant. This bisque capacity is equivalent to that of thirteen $16^1/_2$ ft. diameter periodic kilns which would cost more to build than the bisque tunnel kiln.

The two Continuous Tunnel Kilns built by the Mount Clemens Pottery Company, Mount Clemens, Mich., for firing semi-porcelain tableware and just recently put into operation, are probably unique for several reasons.

First, the two kilns are placed end to end, on the same center line, necessitating probably the longest building in the country used exclusively for housing kilns.

Second, the kiln installation is one of the very few firing white ware, in which coal is being successfully used as fuel.

Third, the kilns are open- or direct-fired and the furnaces are hand stoked without resulting in loss from fluctuating temperatures, reducing conditions or ash deposit upon the ware.

The bisque kiln is 323 ft. 6 in. long and operates at cone 10. The glost kiln is 273 ft. 6 in. long and operates at cone 6.

The building which houses the kilns is 825 ft. long by 70 ft. wide; is of modern daylight factory construction with brick walls, steel sash windows, steel roof trusses and a wide center monitor the full length of the building. Space is provided for a duplicate pair of kilns and also for additional drawing and loading tracks.

[1] Received March 10, 1921. Read at the Columbus meeting, Feb. 1921.

[2] Mount Clemens, Mich.

Figure 1 shows the general layout of the present kilns and also the duplicate installation.

Figure 2 is a view of the charging end of the bisque kiln, showing the rolling steel charging door, a car of ware ready to enter and the hydraulic ram, which will be described later.

Figure 3 shows the battery of five furnaces on one side of the bisque kiln, only three of which are necessary to maintain the kiln temperature. The grates are an "Underwood" pattern, specially designed for these kilns and consist of a cast iron grate plate with a hollow box below connecting into two long tuyeres located on top of the plate and running transversely with respect to the furnace. The inside of the furnace proper measures 24 in. by 27 in. and a fuel bed about 15 in. thick is maintained. The side walls, front wall and bridge wall are air-cooled to prevent clinker building onto the masonry. The air used for this purpose serves as primary air for combustion and enters the fuel bed with steam thru the tuyeres. Manually operated drag chains remove the ashes from the grate plate. Just inside of the charging door is an inclined coking table. A small scoop of coal, about 13 lbs., is charged on to this coking table at 20 minute intervals,—the coke being pushed off the coking table and spread over the fuel bed before fresh coal is added. Three secondary air inlets are provided on each side of the charging door, being supplied with air which is preheated by passing over the crown of the cooling end of the kiln and then over the furnace arch. The furnace throat is greatly enlarged as it enters the tunnel proper, the purpose of which is to reduce the velocity of the furnace gases as they come in contact with the kiln setting.

As these kilns are direct-fired, they are essentially horizontal draft kilns. A characteristic of this type of tunnel kiln (as also with the muffle type, in fact) is that the top part of the setting of ware is subjected to greater heat than the lower portions, due to the tendency for the heated gases to rise in the tunnel and travel in the upper levels. The means employed to compensate for this natural tendency is clearly shown in figure 4, which is a typical

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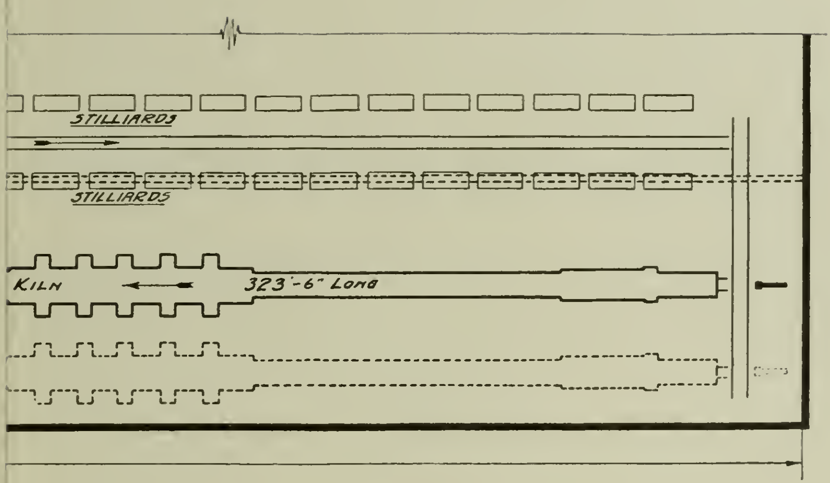

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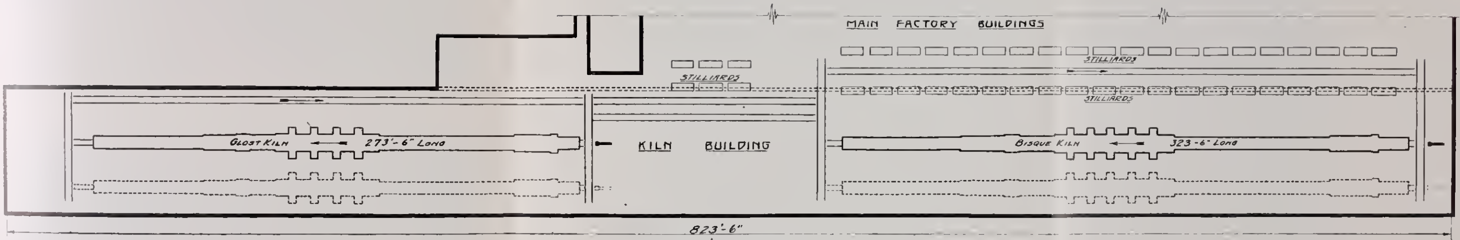

MT. CLEMEN'S POTTERY CO.
MT. CLEMENS, MICH.

FIG. 1.

FIG. 2.

FIG. 3.

cross section through the high temperature zone. Gases will tend to travel through large spaces rather than small ones. Or, stated differently, gases will tend to avoid spaces with great frictional resistance and will seek paths of lesser resistance. Therefore, in the construction shown, even tho there is a tendency for the furnace gases to rise in the tunnel, they will not do so to any undesirable extent, because the free area in the upper part of the tunnel through which they can travel horizontally is so small and presents so

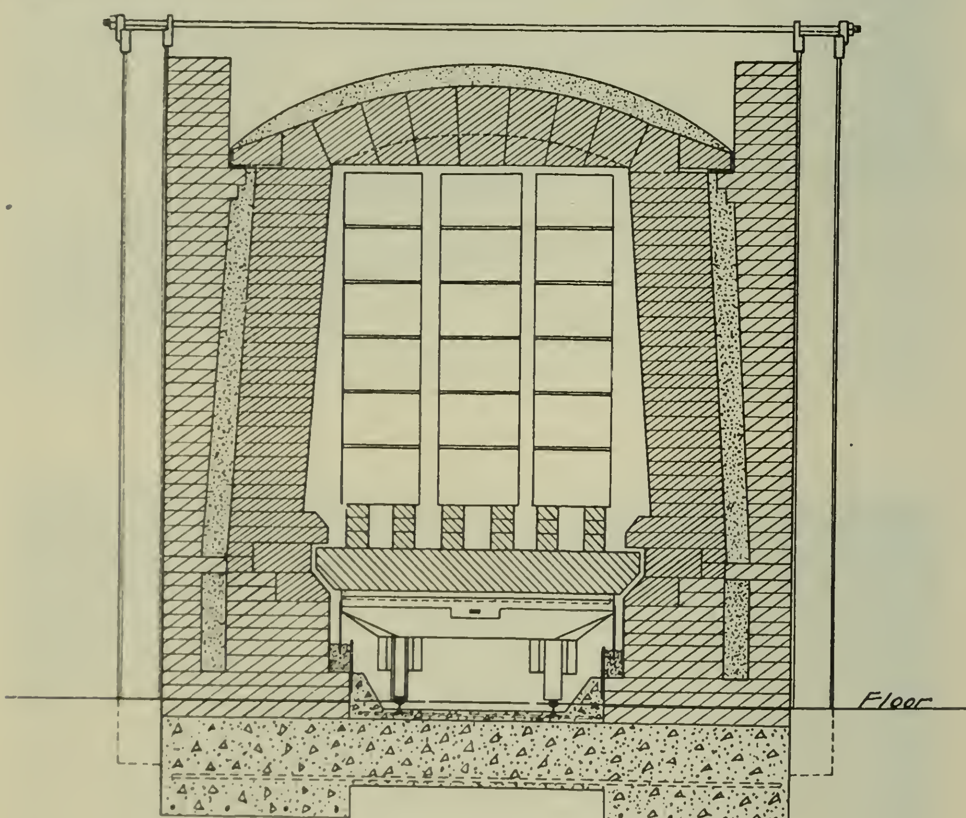

Fig. 4.

much friction that they will naturally seek the larger clearances at the lower levels, including the spaces between the lowest setting and the car platforms. As can be seen from the sectional view, this is accomplished by depending baffles under the kiln crown (or by the use of baffle blocks or stop blocks, superimposed on the car setting), by battering the side walls of the tunnel and by stilting the ware up from the solid car platform, which really never gets as hot as the side walls or crown of the kiln.

This cross sectional view also shows the heat insulation, which is heaviest at the high temperature zone and less towards the ends of the kiln.

The car platform is a single gray iron casting. The wheels are larger than those used in other tunnel kilns, which results in an easier movement of the car. The wheels on one side are double-flanged and those on the other flat-faced. Each wheel is mounted on a separate axle and is equipped with a cage roller bearing. The superstructure of the car consists of $2^1/_2$ inches of heat insulating cement and a single course of refractory blocks 9 inches thick. The car is unusually light considering its size,—the finished top measuring 4 ft. $11^1/_2$ in. wide by 7 ft. $1^1/_2$ in. long.

The mechanical equipment of each kiln consists of a blower driven by a 3 H.P. motor, a draft fan driven by a 5 H.P. motor and a hydraulic ram. The ram was specially designed for these kilns. It is entirely self-contained carrying the oil for operating in a reservoir in its base. The piston returns automatically at the end of its stroke. The triplex oil pump is operated by a variable speed $^1/_4$ H.P. motor.

So far as is known there are no published data as to what force is necessary to move the cars thru a tunnel kiln. It was, therefore, decided to accurately determine this in connection with these two kilns. A pressure gage was connected with the cylinders of both rams and showed that the bisque kiln, holding 44 cars at one time, required a force of 8100 lbs. to propel the train of loaded cars. The force required to propel the 37 loaded cars in the glost kiln is 4860 lbs.

The pyrometric equipment of these kilns consists of one recording and one indicating galvanometer, 15 thermocouples in the bisque kiln and 12 thermocouples in the glost kiln,—noble metal couples being used in the high temperature zones and base metal couples in the cooler parts. Compensating leads and insulated cold junction boxes are provided for all couples.

Several different coals have been tried in these kilns and "Elkhorn" Kentucky gas coal has proven most satisfactory. On February 9th and 10th, at which time the cars were being charged at $1^1/_4$-hour intervals, a very careful fuel test was conducted on the bisque kiln and showed a 24-hour fuel consumption of 6710 lbs.

From this test, 1.22 lbs. of coal are required per dozen of ware. The periodic kiln records at this plant show that the bisque kilns hold 4100 dozen and require 16 tons of coal, or 7.8 lbs. of coal per dozen ware. Comparing these figures, the bisque tunnel kiln requires but 15.6 per cent of the fuel used in the periodic kilns, or there is a fuel saving of 84.4 per cent.

The bisque kiln was planned to operate on a 1-hour car schedule and in order to test the capacity, the kiln was operated for over two days at a car schedule of 55 minutes, or 26 cars per 24 hours. Under this increased production (over 7200 dozen ware per 24 hours), the additional amount of fuel required is practically negligible. With a fuel consumption of 7000 lbs. under these conditions, the fuel saving was 87.6 per cent.

A fuel test was conducted on the glost kiln at the same time, under a 1-hour car schedule,—each car carrying 131 dozen ware. 5670 lbs. of coal were used in 24 hours, or 1.8 lbs. per dozen ware. The periodic glost kilns hold 2900 dozen ware and require 14 tons of coal. This shows a fuel saving in the glost kiln of 81.3 per cent. This kiln was operated for a while on a 37 minute car schedule and at this rate of operation would undoubtedly show a fuel saving of over 90 per cent. The maximum practical rate of car movement has not yet been determined for either kiln, but it is safe to say that the rates tried thus far can be easily exceeded, especially in the glost kiln and without any detriment to the quality of the ware. The foundation's for these kilns were begun the second week in June, 1920, each foundation requiring about one week to pour. Due to delayed delivery of brick, the mason work was not begun until July 26th. The bisque kiln was lighted November 24th and the glost kiln January 12th, 1921.

On the basis of capacities already proven in these kilns, and comparing with their past periodic kiln operation, the bisque tunnel kiln has a capacity equal to 13 periodic kilns and the glost tunnel kiln has a capacity of 11 periodic kilns, or, the two tunnel kilns have already shown a capacity equal to 24 periodic kilns, which at $5000 each would represent a greater investment than the two tunnel kilns complete. As stated before, the tunnel kilns have not been pushed to their limit, so that the above comparison is conservative.

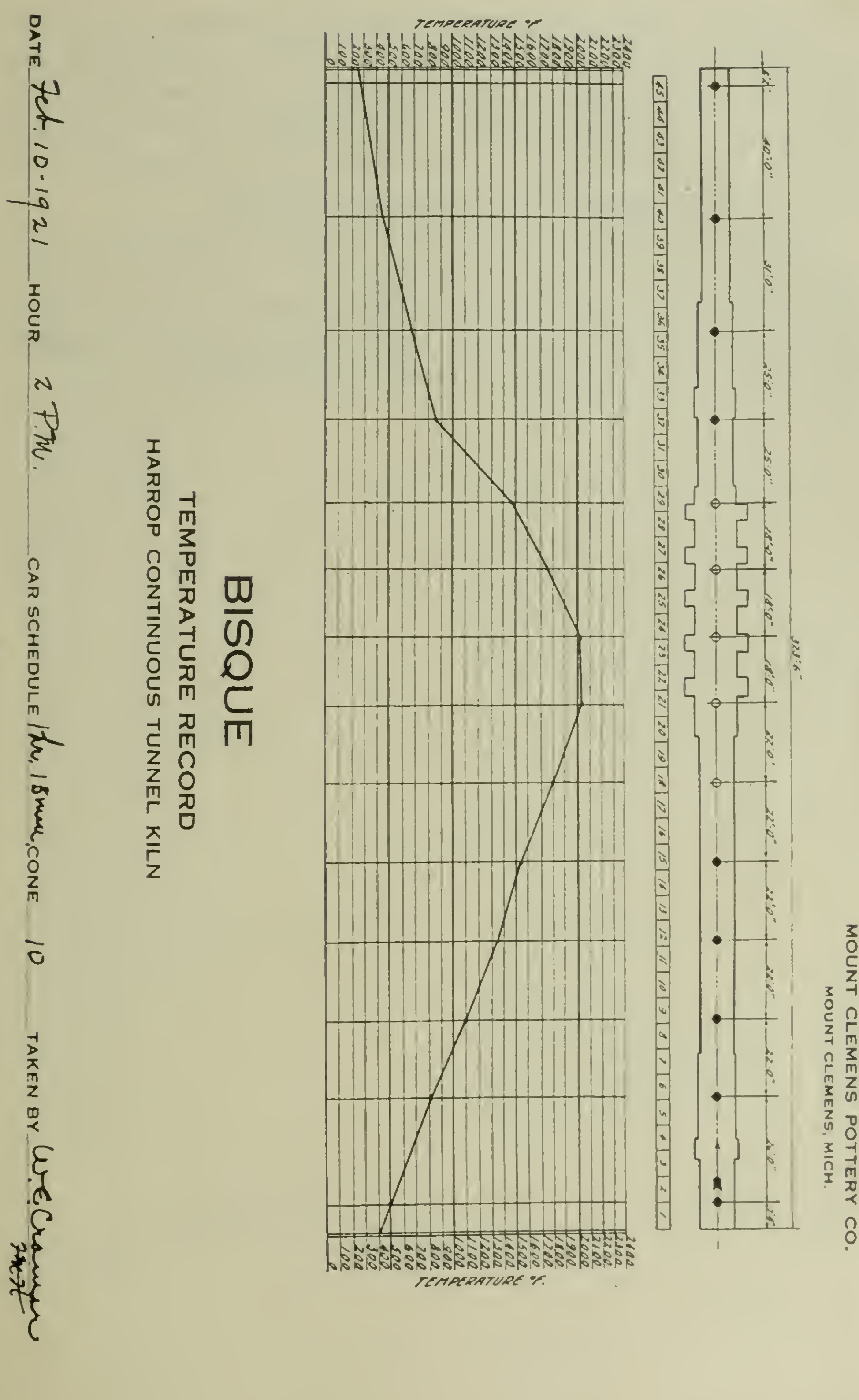
MOUNT CLEMENS POTTERY CO.
MOUNT CLEMENS, MICH.
BISQUE
TEMPERATURE RECORD
HARROP CONTINUOUS TUNNEL KILN
TEMPERATURE °F
DATE Feb. 10-1921 HOUR 2 P.M. CAR SCHEDULE 1 hr. 15 min. CONE 10 TAKEN BY W. E. Cramer

FIG. 5.

In regard to kiln losses, no accurate determination of this has been made. However, in the opinion of the superintendent the loss in the bisque tunnel is much lower than in the periodic kilns. This is to be expected, as there is practically no loss from flashed ware or from over-firing or under-firing, as the temperature and atmospheric conditions are practically constant.

Figure 5 is a temperature record, showing the temperature gradient throughout the length of the bisque kiln and is self-explanatory, although it might be stated that the temperatures noted are taken about 3 inches under the crown of the kiln and do not indicate the temperatures of the ware at the several points.

CERAMIC ABSTRACTS*

Author Index to Abstracts for August

* The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. Possibilities of ceramic industries in Nova Scotia. JOSEPH KEELE, Ottawa Dept. of Mines. *Canad. Chem. Met.*, **5**, 20 (1921). Ed.

2. Distribution of scientific information in the United States. ROBERT B. SOSMAN. *J. Washington Acad. Sci.*, **11**, No. 4, Feb., 1921.—The production of new information in the United States is much better managed than its distribution. It is distributed through five main channels: (1) by personal communication or through the "informational middleman;" (2) by public lectures; (3) by the museum and public exhibition; (4) by the printed page–books, scientific and technical periodicals, bulletins, general periodicals, newspapers, and separates; (5) by the cinematograph. Ineffective distribution results from (1) disinclination to use new knowledge, a cause not discussed in this paper; (2) the inaccessibility of scientific information, arising from (*a*) the bulky form in which it comes from the producer, (*b*) its heterogeneous character, and (*c*) the arithmetical or psychological limitations peculiar to each method of distribution. The bearings of these various factors on existing methods of distribution, both to producers of information and to the general public, are touched upon, and desirable or probable future developments in each are briefly discussed. Ed.

3. Work of the ceramic station of the Bureau of Mines at Columbus, Ohio, in behalf of the ceramic industry. *Repts. Invest. Bur. Mines*, **1921**, No. 2212, 5 p. (*C. A.*)

4. Overhead expenses—How to distribute them in good and bad times. ANON. *Special Rep.*, U. S. Chamber of Commerce, Fabricated Production Department.—The subject is discussed under the heads: elements of a mfg. enterprise; the activities involved; operations cease, but do expenses? the consumer pays? a normal year—the business standard; operation under a normal year basis; necessary cost system adjustments; some misunderstandings clarified; found feasible in practice; conclusion. This and other pamphlets on the same subject will be sent on request addressed to Fabricated Prod., Dept. U. S. Chamber of Comm., Mills Bldg., Washington, D. C. Ed.

5. Lime as a source of trouble in clay. DR. ZIMMERMANN. *Tonind. Ztg.*, **44**, 993 (1920).—When lime is present in clay its tendency to slake may be overcome by soaking the ware in firing sufficient to cause the lime to combine with the clay, thus dead-burning the lime. H. G. SCHURECHT

6. Porous brick and ceramic products. G. B. *Rev. Mat. Constr. Trav. Pub.*, **136**, 11B (1921).—Organic materials such as cut grass, oats, or other cereals, tan bark, coke dust, wood shavings, saw-dust and peat may be substituted for coal to be mixed with clays for making porous products. Such brick are less costly than those made from kieselguhr.

7. Water smoking. ANON. *Rev. Mat. Constr. Trav. Pub.*, **140**, 73B (1921).—Repetition of general principles—no new information.

8. **Rules for the proper drying of large piece and hollow clay ware.** ANON. *Rev. Mat. Constr. Trav. Pub.*, **137**, 24B (1921).—A very general discussion with no new information.

9. **Prevention of scaling of burned clay pipes.** P. S. *Rev. Mat. Constr. Trav. Pub.* **140**, 76B (1921).—Scaling is due to laminations in the clay, poor mixing and grinding of the batch, faulty press machines, and unequal heating in the kilns. Scaling occurs during the dehydration period, 300°–420°, but is in evidence only after salting and during the cooling period.

LOUIS NAVIAS

Apparatus and Instruments

10. **Separation of slimes from liquids by centrifuging.** BERTHOLD BLOCK. Charlottenburg. *Chem. App.*, **8**, 13–6, 23–4(1921); cf. *C. A.*, **15**, 779; 3 cuts.—This is the 6th supplement to B.'s article (*C. A.* **14**, 1872); in it he discusses power consumption. J. H. MOORE (*C. A.*)

11. **Recent developments in grinding.** CARL NASKE. *Z. Ver. deut. Ing.*, **64**, 469–75, 619–22, 980–5, 1109–13(1920).—A review of developments in crushing and grinding machines since 1910, with illustrations. Jaw-crushers, rolls, impact pulverizers. ball mills, tube mills; classifiers. sieves, conveyors, air-transportation systems; revolving furnaces, shaft furnaces; typical grinding layouts for aniline, superphosphate, carbide, ammonium salts, lime and Portland-cement plants, are described. W. C. EBAUGH (*C. A.*)

12. **Works standardization of pyrometers.** R. GATES. *J. Inst. Elec. Eng.* (London), **57**, 317–21(1920). C. G. F. (*C. A.*)

Chemistry, Physics and Geology

13. **Silicic acid.** VICTOR LENHER. Dept. Chem. Univ. Wis. *J. Am. Chem. Soc.*, **43**, 391–6(1921).—**Effect of fine grinding on silica.**—Experiments show that pure water alone will cause finely ground quartz to go into colloidal solution. Similar experiments with orthoclase gave similar results. **Chemical action of water on silica.**—The action of water on silica is that of a solvent to produce a silica gel. The more finely divided the silica, the more rapid the action. The action is accelerated by heat and with water at high pressures the hydration of large sized quartz crystals and of fused quartz takes place readily. At 400° water will slowly gelatinize all fused silica ware on the market today. **Effect of pressure on silica gels.**—Dehydration of silica gels by pressure was investigated up to a pressure of 2200 kg./cm., the water content decreasing continuously with increasing pressure from an original content of 98% down to only a few per cent. Ed.

14. **Record production of borax in 1920.** ANON. *Chem. & Met. Eng.*, **24**, 702(1921).—The quantity of borax produced and sold in the U. S. in 1920 was 35,280 short tons, valued at $5,674,000. This is a record production and value, exceeding even those of 1919—28,518 tons and $4,351,891—which were higher

than those of any previous year. For many years borax has been manufactured in the U. S. from the mineral colemanite, a calcium borate, which is mined in Calif., but for the last two years some borax has also been obtained from the water of Searles Lake, Calif. H. F. S.

15. **Bauxite in West Africa.** *Min. Mag.*, **24,** 189(1921).—From a report by A. E. Kitson, Director of the Geological Survey of the Gold Coast, information is obtained concerning the bauxite deposits of Mount Ejuanema. The bauxite, as exposed in a number of shafts, is within a few feet of the surface and averages $20^1/_4$ ft. in thickness of which $12^1/_2$ ft. is massive and the remainder rubbly bauxite mixed with finely granular red bauxite. An estimate gives the total quantity available as three million tons. A peculiarity of the deposits is the quantity of CO_2 gas apparently given off by the bauxite making some of the workings dangerous unless special precautions are taken.

16. **New talc grinding capacity of the United States.** R. B. Ladoo. *Eng. & Min. Jour.*, **111,** 752(1921).—An abstract of a recent number of the *Reports on Investigations*, U. S. Bureau of Mines.

17. **Mining chrome ore in Turkey.** R. W. Lane. *Eng. & Min. Jour.*, **111,** 749–750(1921).—At Macri on the coast of Asia Minor opposite the Isle of Rhodes, there are a number of chrome mines only five of which are near enough to the shore to be mined profitably. Of these the three largest are operated on a long term lease by an American corporation which sends about 80% of the 25 000 ton output to America and the remainder to Europe. The ore is of good quality, running 40–45% chromic oxide with 6–8% silica. Due to present primitive methods the production is limited but with contemplated modern installation the output will be increased to 100,000 tons.

18. **South American mining fields and practice.** W. H. Stover. *Eng. & Min. Jour.*, **111,** 544(1921).—Besides a discussion of oil and metal mining there is a short description of the occurrence of chromite in Bahia. 30,000 tons of ore running 38–47% chromic oxide have been mined and more than twice that much still remains. The genesis of the ore is not explained but it is stated that it is associated with "quartz, hornblendic rocks" and gneisses. Serpentine, which is usually present in chromite deposits, occurs sparingly.

19. **The origin of graphite.** T. H. Clark. *Econ. Geol.*, **16,** 167–183 (1920).—Most of this paper is given over to a classification and discussion of the various types of deposits. The main object however is to call attention to the possibility of the origin of graphite from the carbon dioxide liberated from limestone by contact metamorphic action.

20. **Mica in 1919.** H. Imsley. *Min. Res.*, **1919,** Part. II, 269–277(1921).—During 1919 the production of sheet mica decreased 6% in quantity and 34% in value from that of the preceding year. The large decrease in value is probably due to a relatively larger production of the smaller and less valuable sheets since the prices for the individual sizes remained the same as the preceding year or showed a slight increase. The production of scrap mica showed

a considerable increase in both quantity and value. Tables are given showing production by states, prices, imports, and exports for the last six to ten years. The last few pages are devoted to short discussions on the Nature and Occurrence, Distribution, Physical Properties, Forms and Classification, and Uses of mica.

21. Talc and soapstone in 1919. J. S. DILLER. *Min. Res.*, **1919**, Pt. II, 265–268(1921).—During 1919 the production of talc showed a decrease of 13% in both quantity and value. North Carolina, Massachusetts, Pennsylvania, and Georgia showed an increase during this period while California, Virginia, Maryland, New York, and Vermont showed a decrease. Tables showing the distribution and value of imports follow a brief discussion of the occurrence and uses of talc. The soapstone production shows an increase of nearly 8% in quantity but a decrease of 8% in value. D. D. SMYTHE

Refractories and Furnaces

22. Convection of heat and similitude; heat-loss results from model experiments. A. H. DAVIS. *Phil. Mag.*, **40**, 692–703(1920).—The heat-losses from a hot body may be due to conduction, radiation, and convection. While the two former may be calculated, if the constants of the materials and surfaces be known, the loss by convection is complicated by its dependence on the geometrical form of the surface. Although for the simplest forms (spheres, cylinders, etc.) the effect may be calculable, in general it can only be found by experiment, using either the actual object or one of similar form. Evidence available in published data indicates that, for heat-loss from a body, an excellent first approximation can be obtained from experiments with a model. The principle of similitude affords a convenient method of expressing experimental results. ED.

23. Refractory materials; ganister and silica rock; sand for open hearth Steel furnaces; dolomite; petrography and chemistry. H. H. THOMAS, A. F. HALLIM and E. G. RADLEY. *British Geol. Survey*, **16**, 1–115(1920).—Gives analysis of various types of silica rock and dolomites together with discussion of the same. Numerous excellent micro-photographs are shown illustrating both the original structure of the refractories and the structure developed after use in the furnace.

24. Experiments in the use of refractories. *Eng. & Min. Jour.*, **111**, 586 (1921).—An abstract of a recent number of the *Reports of Investigations*, U. S. Bureau of Mines.

25. Meeting emergencies at a chromite plant during the war. S. H. HAMILTON. *Eng. & Min. Jour.*, **111**, 712(1921).—Describes emergency methods used in chromite treatment in N. Carolina due to lack of supplies during the war.

26. **Foreign graphite in 1919.** A. H. Redfield. *Min. Res.*, **1919**, II, 181–210(1921).—Gives data on the production of graphite in all of the important foreign localities. A number of maps illustrate the locations of the fields and a graph is given showing the relative production of the various countries from 1910 to 1919.

27. **American clay in graphite crucibles.** *Eng. & Min. Jour.*, **111**, 592 (1921).—An abstract of a recent number of the *Reports of Investigations*, U. S. Bureau of Mines.

28. **Chromite in 1919.** J. S. Diller. *Min. Res.*, **1919**, I, 87–91(1921).—Due to the decline in prices a little over one-third of the chromite produced in the United States in 1918 was left unsold. As a result there was a decrease of nearly 94% in the production during 1919. Tables are given showing chromite production by various states and counties, also a list of producers most of whom are located in California. The imports of chromite (for which a table is also given) show a drop which is not nearly as large as that of the domestic production.

29. **Magnesite in 1919.** C. G. Yale and R. W. Stone. *Min. Res.*, **1919**, I, 227–235(1921).—During 1919 the production of domestic magnesite fell off 32%. Some magnesite was imported from Europe and Mexico but the imports from Canada fell off resulting in a decrease of 24% in the imports. In the early part of 1919 the domestic producers were nearly all shut down due to the buyers holding off in expectance of cheap foreign material. This supply did not develop and as a result the buying of domestic magnesite was resumed. A bill designed to protect the domestic industry was introduced in Congress in 1919 but has not been enacted into law as yet. The last few pages of the paper are devoted to short descriptions of the various localities in California, Washington and New Mexico. D. D. Smythe

30. **Air cracks in refractories.** Dr. Fischer. *Tonind. Ztg.*, **44**, 1270 (1920).—F. differentiates between air cracks and shrinkage cracks. Air cracks are caused by rapid heating and cooling while shrinkage cracks develop during firing. Air cracks are very fine while shrinkage cracks are wide. When a piece of the ware is broken it usually cracks along the air cracks. H. G. Schurecht

31. **Cements for joining refractory bricks.** Anon. *Rev. Mat. Constr. Trav. Pub.*, **136**, 11B(1921).—The effects of the addition of various materials on the fusibility of a clay are given. The fusion temps. are given in cones.

Materials Added

% of material added	Portland cement	Lime	Asbestos	Salt	Carborundum	First class refractory brick waste
0	30	30	30	30	30	30
3	..	..	28–29	..	..	..
4	27	20–26	..	..	..	..

% of material added	Portland cement	Lime	Asbestos	Salt	Carborundum	First class refractory brick waste
5	..	..	..	26	29	..
6	20	..	19–20	..	..	..
8	19	17–18	..	..	..	..
9	..	..	18–19	..	..	..
10	15	..	..	14	29	..
12	..	11	..	..	..	..
15	..	..	..	5	29	..
16	..	10	..	..	..	..
20	13	..	..	..	29	..
24	..	..	..	..	..	..
25	..	..	..	..	..	30–31
30	11	..	..	..	29	..
40	8	..	..	..	29	..
50	..	..	..	..	29	31

Carborundum and refractory brick maintained the refractoriness,—the rest of the materials lowered it considerably. LOUIS NAVIAS

32. A refractory manufactured from mica. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 15B(1921).—The waste mica from porcelain factories is mixed with clay or with clay and crushed quartz and fired to a temp. sufficiently high to fuse the mica. The resulting product is a good refractory and a good electrical insulator. ED.

33. The recovery of heat from flue gases, and the reheating of air. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 6B(1921).—The heat in flue gases may be utilized in a "recuperator" to preheat air going to the fire-box or to dryers. The "recuperator" may be made of ceramic material or of iron or steel,—the first being used for gases of very high temps. The iron or steel "recuperators" come in either tube form or in plate form, the latter form having the greater advantage of (1) better contact of the gas and air with the separating walls,—for alternate layers of air are heated by alternate layers of the flue gases 25 to 30 mm. apart; (2) less resistance; (3) greater surface area for the space occupied. Compared with an "economizer" the "recuperator" is more gas-tight, thereby preventing the entrance of cold air into the hot gas chambers; and is only one-sixth as heavy for equal surface areas. There are two kinds of plate "recuperators"—the first consisting of semi-circular plate air sections, between which the flue gases travel parallel to the diameters. The different paths travelled by the gases and air, make it difficult to obtain good circulation. The second type known as the "Thermix" is composed essentially of ordinary sheet iron and a frame work of small U irons and coils. The coils allow the fluids to drain off, and also help to tighten the joints of the vertical column of plates. The drainage system can be adapted to any particular case. "1 lb. of 'recuperator' will save 50 times its weight of coal."

34. How to insulate a ceramic furnace. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136,** 10B(1921).—Describes the properties of Sil-o-Cel.

35. **Certain types of testing furnaces used in the ceramic industries.** C. MIRA. *Rev. Mat. Constr. Trav. Pub.*, **136**, 1–5B; **137**, 17–20B(1921).—A description with figs. of various types of testing furnaces described in American and English literature.

36. **The water proofing of kiln crowns.** BRICK. *Rev. Mat. Constr. Trav. Pub.*, **136**, 12B(1921).—Over the arch is laid, first, an 8 cm. layer of coal cinders then a 3 cm. layer of ground clay and lastly a layer of asbestos sheeting. Over all is put a layer of special tile. These are hollow rectangular tile, each having at one side a protruding cover that overlaps the next tile in its row. The process of mfg. the tile is patented. LOUIS NAVIAS

37. **The firing of ceramic ware with petroleum.** J. THOMAS-CADILHAT. *Ceramique*, **23**, 145–149(1920); *Tonind. Ztg.*, **45**, 36(1921).—In the stoneware potteries of Mexico, petroleum has been successfully used since 1919. The ware is fired in cylindrical kilns built for coal-firing and slightly changed for the new system of firing. The advantages of petroleum-firing over coal-firing are as follows: 1—A more uniform heat is obtained; 2—the kilns are not chilled by removing ashes as is the case in coal firing; 3—less labor is required; 4—less upkeep is necessary with grate bars; 5—no ashes, dust or slag are obtained; 6—a better control of temp., fuel consumption and kiln atmosphere is possible and 7—it is easier to start and shut off the fire. With a 90 cbm. kiln one pottery reaches cones 9–10 in 24 hrs. and cone 1 in 22 hrs. H. G. SCHURECHT

38. **A new physical aid in ceramics.** K. M. BALLEY. *Chem.-Ztg.*, **45**, 75(1921).—Ceramic wares when burned even in muffle or sagger kilns, are often ruined by kiln gases. This may be overcome by maintaining a suitable atm. within the muffle or sagger under a pressure about 5 mm. of H_2O greater than that of the kiln atm. An oxidizing atm. is maintained with air or acid vapors, a neutral atm. with CO_2 or N_2 and a reducing atm. with H_2O or CO. C. H. KERR (*C. A.*)

39. **Coal-dust firing in America.** HUGO BANSEN. *Stahl u. Eisen*, **40**, 1162–5, 1196–1201, 1228–35(1920).—A symposium based on papers in various technical journals. CARLE R. HAYWARD (*C. A.*)

40. **Analyzing records of carbon dioxide and combustible gases.** ANON. *Elec. World*, **77**, 654(1921); 1 illus.—The chart shown emphasizes the importance of keeping continuous records of combustible gases present in the flue. C. G. F.(*C. A.*)

41. **Percentage of carbon dioxide is not final test of good combustion.** O. RODHE. *Elec. World*, **77**, 429(1921).—Dependence on CO_2 records alone is misleading, for while low CO_2 generally indicates excess of air, it may indicate poor mixt. of the air. Insufficient air supply causes the presence of CO in the stack, but other influences include poor furnace design, improper firing methods, the use of the wrong quality of coal for the equipment, poor mixt. of the combustible gases and air, and low furnace temp., whereby the gases are cooled below the ignition point before combustion is complete. W. H. BOYTON (*C. A.*)

42. **Kinds of chimney losses and their relative importance.** O. RODHE.

Elec. World, **77**, 544(1921).—Heat losses in chimneys are either sensible heat of the flue gases or the heat represented in chem. energy in unconsumed combustible gases. Curves show flue losses with varying amounts of CO_2. At the critical point combustion takes place with the greatest economy in fuel consumption. (*C. A.*)

43. **German naval specifications for fire-brick used in boiler settings.** *Mitt. der Brennkraftechnischen Gesellschaft*, **2**, 51–56; **8**, 57–59; *Tonind. Ztg.*, **44**, 1097–1098(1920).—Heavy dense brick should be used in contact with the coal bed, medium heavy, for contact with flames only and light brick for the remainder. For a no. 1 brick, deformation should be above cone 34, for a no. 2 brick, cone 31–33 and for a no. 3 brick, cones 26–30. The brick in contact with the fuel bed should contain at least 38% Al_2O_3. For a mortar a mixt. of grog and fire clay is specified which vitrifies at cone 10 and has a deform. point of cone 34. H. G. SCHURECHT

44. **Clearing of service pipes with highly compressed air or carbon dioxide.** F. GRUBER. *Z. Ver. Gas.-Wasserfach*, **61**, 8–9(1921).—Use of compressed air or CO_2 to clear stoppages in service pipes leads to slugs of non-inflammable or explosive gas in the mains, resulting in dangerous extinctions of gas flames or explosions that damage meters. A case of meter damage in Vienna is discussed. ERNEST W. THIELE (*C. A.*)

45. **Silica bricks for coke ovens.** J. ENZENAUER. *Stahl u. Eisen; Iron & Coal Trades Rev.*, **102**, 232–3(1921).—The Rheinische Stahlwerke has carried out comparative tests on each of 2 batteries of coke ovens, one made of silica bricks with lime binder of compn. Al_2O_3 1.6–1.9%, SiO_2 94.5–95.0, Fe_2O_3 1–1.5, CaO 1.8–2, MgO 0.1–0.15, alkali 0.6–0.8; the other with ordinary clay-bound fire-brick of compn. Al_2O_3 15–17%, SiO_2 79–81, Fe_2O_3 1.8, CaO 0.3, MgO, 0. 3, alkali 1.6. The former has been in use 4 yrs , the latter 3, and yet the former is in much better condition, silica brick being much more resistant to corrosion from salty and wet coals, to slagging and fusing, and to mechanical abrasion. Also, contrary to expectations, the yield of sulfate was not impaired. The time of coking a charge was reduced from 29 to 24 hr. and 18 hr. was thought feasible. The coke from the silica ovens is of better appearance and considerably harder than that from the fire-brick ovens. In spite of the irregular working, the walls have not developed troublesome leaks and losses of gas are rare. The economic efficiency of the plant is very high. Numerical data were obtained on the differences existing between the working of the silica and fire-brick ovens, resp., comprizing the following detns.: gas made per ton of coal with equal charges 10,675–10,790 cu. ft. per battery per hr. 202,450–170,000 cu. ft.; gas consumption per hr. 126,370–105,600 cu. ft.; heat consumption per ton of coal 692–697 cal.; flue temp. 1069–1027°; stack temp., 372–327°; temp. of blast and regenerator gas 1040–993°; temp. in oven 908–804°; temp. of distn. gas in upcast, 456–434°, in receiver, 295–270°; compn. of crude gas % C_nH_m 2.0–1.9, CH_4 22.1–21. 2, H_2 57.6–58.1, CO 5.1–4.5, CO_2 1.8–2.1, O_2 0.5–0.3, N_2 10.8–11.9, cal. per cu. m., 3809–3770; compn. of flue gas % CO_2, 7.3–7.0, O_2 5.5–5.6, surplus air, 29.6–33.3. J. L. WILEY (*C. A.*)

46. **Tentative test for slagging action of refractory materials.** ANON. *Proc. Am. Soc. Testing Materials,* **20,** I, 620–3(1920).—A tentative standardized test is recommended by Com. C-8 of the Am. Soc. Test. M. The brick to be tested has a refractory ring cemented to its surface. The whole is held at 1350° during the test. Thirty-five grams of synthetic slag, ground to 40-mesh is put within the ring and allowed 2 hrs. to soak in. The brick is finally cut open and the area of penetration measured. The synthetic slag for general use is made to analyze; SiO_2, 19.0; Al_2O_3, 12.89; Fe_2O_3, 15.73; CaO, 33.50; MgO, 6.93; MnO, 3.52; Na_2O, 8.50. The m. p. of this slag is 1270°.

C. H. KERR (*C. A.*)

Silica bricks for coke ovens (ENZENAUER) **21.**

47. **Magnesite in 1919.** CHARLES G. YALE AND RALPH W. STONE. U. S Geol. Survey, *Mineral Resources of U. S.,* 1919, Part II, 227–35 (preprint No. 14, published Mar. 7, 1921). E. H. (*C. A.*)

48. **Polymultiple flame combustion in metallurgical furnaces.** ANON. *Genie civil,* **76,** 336–7; *Mech. Eng.,* **42,** 405–6(1920).—The principle and the method of operation of the Chantraine metallurgical furnace are described. If a jet of gas passes into air as in an ordinary furnace, combustion occurs on the periphery of the jet, and heat radiates mainly into the air, which is permeable to radiant heat. If a jet of air enters an atm. of combustible gas, the heat radiation nearly all remains in the air of the jet, because the adjacent unburned combustible gas is practically impermeable to radiant heat. The tip of such a flame is many times hotter than that of a flame produced by burning a gas jet in air. The combustion is practically perfect even with a very slight excess of air. The Chantraine furnace consists of a double roof, the lower part of which is perforated. The air enters through regenerators, and fills the space in the double roof, passing thence down into the furnace. Gas is conducted from producers to the furnace, which it enters at a point just under the perforated roof. The rate of gas flow is so adjusted that there is a continuous sheet of combustible gas under this entire perforated roof at all times. Air enters through the multitude of perforations and combustion takes place in the form of jets of flame, which attain a max. temp. because the heat of combustion radiates back into the air itself, rather than through the sheet of combustible gas, which is practically impermeable to such radiation. The products of combustion are exhausted solely by the pressure in the combustion chamber, whereas in the furnace of ordinary type much heat is wasted by overheating the sides and roof of the furnace. Such overheating does not take place in the Chantraine system because the sheet of combustible gas protects the roof and sides and, further, because the air entering through the perforations in the roof keeps down its temp. The heat is conveyed very directly and efficiently by the compact bundle of jets or darts of flame to the charge in the furnace. Undesirable oxidation may be prevented and an economy of fuel as great as 40% may be effected. Maintenance costs and metal losses are lower. Steel melting and reheating furnaces may be advantageously constructed on this system. JAS. O. HANDY (*C. A.*)

49. Heat flow in the checkerwork of blast stoves and regenerative chambers. G. NEUMANN. *Stahl u. Eisen*, **40**, 1473–9(1920).—The thickness of the brick is not so important as previously supposed. Aside from lessening the heating surface bricks 8 cm. thick can be used. Practically nothing is gained by replacing the clay bricks in the lower part of the Cowper stoves with cast iron. The surface works most efficiently in prolonged heating and an equal period of cooling. Tests where the wind period was less than the gas period were less efficient. CARLE R. HAYWARD (*C. A.*)

50. Waste-heat utilization. G. R. MCDERMOTT AND F. H. WILLCOX *J. Western Soc. Eng.* (Chicago), **26**, 60–76(1921).—The gases leaving regeneration or recuperation furnaces commonly waste 35 to 55% of the total heat available in the fuel fired. Non-regenerative furnaces may waste as high as 80%. Much of this heat is not only recoverable but in 1 yr. will yield returns netting 25 to 75% of the cost of installing equipment. This paper refers principally to the waste-heat fire-tube boilers for open-hearth furnaces developed by Bacon for the Ill. Steel Co. at So. Chicago. Specific figures are cited showing amts. of waste gases from certain typical heats and the principles of their utilization are discussed. S. D. KIRKPATRICK (*C. A.*)

PATENTS

51. Lining for rotary kilns or furnaces. A. F. MEYERHOFER. Can. 209,766, Mar. 22, 1921. The lining consists of an inner layer containing a high percentage of fused alumina and an outer heat-insulating layer. (*C. A.*)

52. Refractory material. AUGUST PFAFF. Can. 209,700, Mar. 22, 1921. A refractory material contains a burnt mixt. of about equal parts of zirconia and silicon carbide. (*C. A.*)

53. Combined boiling, crystallizing and calcining furnaces. ALEXANDER ROY. Can. 210,006, Mar. 29, 1921. The app. comprizes a calcining, a drying, a crystg. and a boiling chamber opening successively the one into the other, and means for supplying a heating medium to the calcining chamber. (*C. A.*)

Abrasives

PATENTS

54. Ceramic grinding-wheels. CARBORUNDUM CO. Brit. 155,076, Oct. 15, 1919.—Cracking round the arbor holes of large grinding wheels, composed of abrasive materials or graded abrasive grains bonded together by clays, Na silicate, or org. bonding material, is prevented by making the part round the arbor hole of less d. or with coarser grains than that of the remaining portion of the wheel. The same bonding material may be used for the inner and outer portions or different bonding materials which mature at approx. the same temp. The material near the arbor hole may have no abrasive properties. (*C. A.*)

White Ware and Porcelain

55. The effect of calcination of flints on earthenware bodies. A. HEATH AND A. LEESE. *Pottery Gaz.*, **46**, 616–618(1921).—The sp. gr. of flint may vary from 2.6 to 2.2 according to calcination temp. It is common practice to calcine

one lot of flint in "hardening-on kilns" and another lot in bisque kilns which produces two different products; that which had been calcined at the high temp. would have a sp. gr. of 2.312 while that calcined at the lower temp. would have a sp. gr. of 2.481. This would mean that 32 oz. of slop flint per pt. would contain 21.146 oz. of dry hard calcined flint or 20.102 of easy calcined flint, *i. e.*, a difference of 5%. To compare the effects of the two in an earthenware body, plates were made of bodies containing the same. After firing, it was found that plates containing the hard-fired flint shrank 4% while those containing the easy-fired flint shrank 5%. The porosity of the bodies containing hard-fired flint was 20.09% while that of the bodies containing the easy-fired flint was 17.83%. On submitting the plates to crazing tests it was found that the plates made with easy fired flint crazed first. In a discussion Grimwade stated that when flint is fired to cone 3a it has a bluish cast. Mellor explained that this was due to the sulphur present which forms ultramarine blue with the flint. H. G. SCHURECHT

56. Recent research in manufacture of porcelain insulators. ALFRED SILL. *Elec. Rev.*, **78**, 389–92(1921).—A carefully prepared review.

C. G. F. (*C. A.*)

57. Burning stoneware. CH. S. *Rev. Mat. Constr. Trav. Pub.*, **140**, 67–69B(1921).—Stoneware bodies containing considerable quantities of lime, should not be heated above cone 4a, for the lime tends to form silicates, that are both fluid and corrosive, penetrating the pores and attacking the less fusible materials; while magnesia gives under similar conditions very viscous silicates, whose chemical reactions are retarded by their poor mobility. The opposite results are true of magnesia at temp. above that obtained in the burning of stoneware. Feldspathic stoneware, without lime, may be heated to the fusion point of the feldspar—cone 9 or 10. Clays for stoneware should be plastic, and attain their maximum shrinkage at relatively low temperatures, *i. e.*, between cones 07a and 4a. Their large iron content colors them brown unless sufficient lime is present to whiten them. If sulphates are present in the body, a basic or neutral glaze, fusing between cones 01a and 05a should be used. In the absence of sulphates an acid glaze is preferable. Fuel free from sulphur compounds should be used, otherwise sulphates will be formed, and will attack the acid glaze. Firing should be carefully manipulated, to allow for the burning out of the carbonaceous matter and for the proper oxidizing of the glaze.

58. Furnace atmospheres and some of their effects on lead glazes. F. BIGOT. *Rev. Mat. Constr. Trav. Pub.*, **137**, 20–21B(1921).—On firing a body glazed with a glaze consisting of a mix. of minium (Pb_3O_4) and silica, the glaze was found to be only slightly fritted and non-vitrified altho the body itself was well burned. The clay employed was found to contain large lumps of decayed wood containing sulfur in various stages of oxidation. Rapid heating to the maturing temp. gave the same fritted results, while slow heating and maintaining the temp. at incipient redness, for a while gave properly glazed pieces. The following reactions were found to take place. The minium

at high temp. gives up some oxygen ($Pb_3O_4 = 3PbO + O$) which combines with the sulfur dioxide, ($SO_2 + O = SO_3$), the sulfur trioxide in turn combines with the litharge ($PbO + SO_3 = PbSO_4$) thereby yielding lead sulfate, an inert compound. By this means little or no lead oxide is left to combine with the silica, and to vitrify. Weathering sulphur-containing clays will oxidize the sulfur oxides to the sulfate. Maintaining the temp. of the ware at dull red heat will oxidize the carbonaceous matter at a temp. too low for it to reduce the sulfates present, and will also remove the sulfur oxides by calcination, thereby leaving the lead in the form of oxide for the vitrification at the higher temps.

LOUIS NAVIAS

Brick and Tile

59. Crystal glazes for stove tile. ANON. *Tonind. Ztg.*, **45**, 12(1921).—The compn. of some of the glazes experimented with are given below:

	1	2	3	4	5
Pb_2O_3	91	118	141	182	185
ZnO	40	32	24	..	6.5
$CaCO_3$	10	..	..	7	5
SiO_2	60	48	55	60	75
H_3BO_3	25	..	..	...	...
Kaolin	..	15	..	...	15
Feldspar	..	44	44	55	22
Rutile	..	32	16	24	12.5
Molybdic acid	..	..	..	5.5	4

No. 1 was fritted and Fe_2O_3, NiO and CuO added as coloring oxides. The resultant crystals were small and not well formed. No. 2 gave a matt with considerable crystal formation. No. 3 also gave a matt. Expts. were conducted in which rutile and ZnO were replaced by the acids of W, Mo, and V. Star shaped crystals were obtained. Glazes with W, ZnO and rutile showed many small opaque crystals. V produced matt glazes. Glazes with more than 0.15 Al_2O_3 were matt with some crystals. Al_2O_3 free glazes produced the best crystals. Lime is necessary since the CaO-free glazes showed only weak crystallization. The best coloring oxides are CoO and CuO. UO_2 was satisfactory in some cases. Glazes containing Fe_2O_3, Mn_2O_3, and NiO were limited only to small crystals. Glazes 4 and 5 are used in the unfritted condition and were fired in 20–24 hrs. on a body consisting of 10 stoneware clay, 20 kaolin, 35 quartz, 8 feldspar and 7 chalk.

60. Plaster molds for roofing tile. H. Kl. *Tonind. Ztg.*, **45**, 57–58(1921).—1700–2000 gms. of plaster of paris is used per l. of H_2O. The plaster should be slowly added to the H_2O rather than the H_2O to the plaster to prevent the formation of lumps. The plaster is then further mixed by means of a beater similar to an egg-beater to produce a more homogeneous mixt.

H. G. SCHURECHT

61. Standardization of brick in Germany. Anon. *Rev. Mat. Constr. Trav. Pub.*, **136**, 10B(1921).—Building brick consist of burned materials of clay, argillaceous earth, or clay partially replaced by sand, crushed quartz or calcined clay. They are divided into three classes (1) "clinkers" having a resistance to compression of 350 kgs. per sq. cm.,(2) hard burned brick with a resistance of 250 kgs. per sq. cm.,(3) building brick of two varieties (*a*) having a resistance of 150 kgs. per sq. cm. (*b*) having a resistance of 100 kgs. per sq. cm. All the bricks should have dimensions 25 cms. long, 12 cms. wide and 6.5 cms. thick. If it is impossible to manufacture them this size the relation between ength, width, and thickness shall be 4:2:1. The limiting absorption for "clinkers" is 5%, for brick of 2nd. class 8%, the others not determined. All brick should withstand the freezing test. The brick are immersed 25 times in water at —4°C and for periods of 4 hours. Louis Navias

Bricks

62. The transformation of periodic kilns into a continuous system in a large brick plant together with a description of the plant. Anon. *Rev. Mat. Constr. Trav. Pub.*, **136**, 8–10B(1921).—Descriptions of the changes made by the Citadel Brick and Paving Block Co. of Quebec, Can. with figs. taken from the *Brick and Clay Record.*

63. Lime-silica (building) brick. (Last installment.) C. Bing. *Rev. Mat. Constr. Trav. Pub.*, **136**, 5B(1921).—A study of the details of manufacture of lime-silica brick, lead to the conclusions that (1) a chemical analysis of a sand does not determine its value as an ingredient for brick making. An impure sand may have necessary physical properties not possessed by a pure sand. (2) Lime slaked to the proper degree can always be made or obtained. (3 The simpler the brick machine the better is the product. It is unnecessary to make a stronger brick than that required for the safe carrying of the load. Thus a six-story house, has at its base a load of 4 or 5 kg. per sq. cm. (4) The cost of labor shou'd be at a minimum. (5) The firing of the brick should be carried on by experienced men—thereby reducing the cost of fuel. (6) Careful inspection of outgoing products will save much of the expense of replacing damaged material.

64. Resistance to compression of crude clay bricks and masonry. T. Z. *Rev. Mat. Constr. Trav. Pub.*, **136**, 12B (1921).—Due to the shortage of coal in Germany, clay bricks in the dry state have been used for building purposes. Tests on such brick showed the following resistance to compression. The 1st column is for dry brick, the 2nd for brick after being 4 weeks in a moist atmosphere. The 3rd column represents the absorption.

	Kgs. per sq. cm. (1)	(2)	(3)
Machine made	42.3	27.2	1.09
" "	34.9	21.1	1.02
Hand made	30.9	21.3	1.12
" "	26 1	20.1	0.76

A test made on some pillars composed of 3 to 8 crude brick had a resistance of 9 to 37.1 kg. per sq. cm. while the resistance of normally burned brick is 150 kgs. for 1st quality and 100 kg. for 2nd quality brick. LOUIS NAVIAS

65. Standardization of specifications for building materials, ceramic product. ANON. *Rev. Mat. Constr. Trav. Pub.*, **136**, 7B (1921).—The French standards comm. has adopted the specifications of the tech. comm. of the Minister of War. Machine-made tile, two sizes, 13 and 22 resp. to the sq. m. Texture homogeneous, free from obvious cracks and laminations; ring, clear; color, uniform; surface sufficiently flat to engage an adjoining tile for $^2/_3$ of the distance; frost resistant; free from particles of uncombined lime; cross-breaking strength 100 kg; the last two tests to be made according to the methods established by the testing lab. of the Conservatoire des Arts et Méteirs. ED.

See also No. 75.

Glass

66. Melting-point of glass. F. WEIDERT AND G. BERNDT. *Z. tech. Physik.*, **1**, 121–3 (1920).—The temp., in an elec. furnace, at which a 25 mm. cube of glass embedded in kieselguhr with a diagonal vertical completely flatten out is called the flowing temp. and the temp. at which the apex just starts to flatten, the deformation temp. The mean of these two temps., which only differ by about 20°C, is called the m.p. The following table gives the flowing temp. for several types of optical glass held at the given temp. for the times given.

Glass type (index and ν value indicated)			Flowing temp. in °C		
			½ hr.	2 hr.	6 hr.
	Crown	510/634	850	815	775
	Crown	516/640	810	795	780
	Flint	549/461	740	725	685
Ba	Crown	573/575	910	885	860
Ba	Flint	580/538	845	805	785
Ba	Crown	590/612	845	830	795
Ba	Crown	609/589	870	835	820
	Flint	613/369	730	695	680
Ba	Crown	614/564	840	815	800
Ba	Flint	626/393	780	730	685
	Flint	649/338	660	645	630

E. N. BUNTING

67. Celon sands for glass manufacture. ANON. *Bull. Imp. Inst.*, **18**, 174–89(1920).—Eighteen samples of sand from dunes near the Jaffna Peninsula on analysis were found to contain from 96.6 to 99.2% SiO_2. In but 2 samples were the heavy mineral and Fe_2O_3 content low enough (0.02 and 0.12%) to permit the use of the sand for the manuf. of the best quality glass; and in those 2 cases the mechanical condition was such that grinding would be necessary. The sand could be used for the manuf. of a glass of medium quality. R. L. SIBLEY. (*C. A.*)

PATENTS

68. **Glass Working, Glass Manufacture.** J. Kent. Brit. Pat. 153,824. Feb. 28, '20; *Ill. Off. Jour.* (Pats.) 1670.P.6057, Jan. 19, 1921. Relates to a method of producing a bore in glass without blowing A sealed length of glass tubing, exhausted, or containing gas, is applied to a mass of glass and autogenously united to and then incorporated with it. The combined mass is afterwards shaped to the desired form. Sketches illustrating the method are included.

69. **Glass Working Electric Lamp Bulbs. Glass Manufacture.** E. A. Kruger. Germany, Brit. Pat. 156,573; *Ill. Off. Jour.* (Pats.) 1677.P.278, Mar. 9, 1921.

Welding. Relates to the process of dividing glass articles such as electric lamp bulbs, into two parts, and subsequently re-uniting the parts by fusion. According to the invention the line of division follows the direction which insures that the parts are afterwards brought together. Wm. M. Clark

Enamels

70. **Porcelain enameling furnaces.** C. G. Armstrong. *Chem. Met. Eng.*, **24,** 486–488 (1921). (Paper presented before Chicago Sec., Amer. Ceramic Soc.) —The art of enameling originated in Egypt about 1300 B. C. Enameling of cast iron for industrial purposes was begun in 1850 and of sheet steel in 1860. The first American plant was built at Woodhaven, N. Y. in 1863. At present both full-muffle and semi-muffle furnaces are used, the latter type being more economical of heat but not suitable for coal firing on account of deposition of ash on ware. Elaborate flue systems in the upper walls and roofs of furnaces are seldom useful in extracting heat from waste flue gases and often are a means of extracting heat from the furnaces and causing the flue gases to leave the furnaces at a higher temperature than if they were taken out by means of shorter flues. The logical procedure is to use a recuperator or to use a thin muffle of high conductivity. Carborundum refractories have comparatively great strength at high temp. and a conductivity about 7 times that of fire clay. The use of thin carborundum muffles permits operation with a temperature difference of only 200°F between flue gases and interior of muffle, as against 800° with fire clay. This gives a fuel saving of about 30% and muffle and flue repairs are greatly reduced. H. F. S.

PATENTS

71. **Purifying clay, sand or similar materials.** G. A. Hulett. U. S. 1,368,396, Feb. 15. Fe and other volatilizable substances are removed from clay, sand or similar materials by heating the material to 350–600° and treating it with phosgene until the volatilizable substances are eliminated. The method is especially adapted for prepg. ingredients of optical glass or clay pots for glass-making.

72. **Quartz-glass articles.** J. Scharl. U. S. 1,368,990, Feb. 15. Quartz is heated to a plastic mass in an elec. resistance furnace about a resistance core,

a space being provided between the quartz to be heated and the resistance core by inserting between them a heat-resisting tube such as C impervious to gases for allowing the escape of the gas formed around the core during the heating. (*C. A.*)

Cement, Lime and Plaster

73. The strengths of high magnesia, hydraulic and common limes. ANON. *Tonind. Ztg.*, **44**, 2–3 (1921).—Mortars were prepared of 1 part lime and 3 parts sand and tested for tens. strength after 28 days.

	In air	In water
High magnesia lime........	3.4 Kg./cm².	1.2 Kg./cm².
Hydraulic lime............	3.7 "	2.8 "
Common lime............	2.5 "	... "

The results show that dolomitic limes as well as hydraulic limes produce stronger mortars than common lime.

74. A mortar material of Anhydrite. H. E. SACHSE. *Tonind. Ztg.*, **44**, 1017–1018 (1920).—Hartner found that Anhydrite ($CaSO_4$) ground extremely fine and mixed with water sets to a hard cement especially if the mixt. is alkaline. The action is facilitated by adding 1–3% of lime or Portland cement. The cement is different from Estrich plaster or plaster of Paris. Plaster of Paris when finely ground has very little residue on 4900 mesh sieve (*i. e.*, 177$^1/_2$ meshes per linear inch). When 100 gms. of water are added to 130–170 gms. of plaster of Paris it commences to set in 1$^1/_2$ to 8 mins. The tens. strength is about 17 kg./ cm². and the compress. strength about 100 kg./ cm². With Estrich plaster about $^1/_2$ passes 4900 mesh per cm². sieve. When 100 gms. of water are added to 280–350 gms. of plaster it sets in about 30 hrs. and develops a tens. strength of about 17 kg./cm². The compress. strength becomes 200 kg. cm². after 14 days and 230 kg./cm². in 28 days. Anhydrite cement was ground to different degrees of fineness and strength tests were made. Sample A was ground until 10% residue remained on a 4900 mesh sieve. B was ground twice as long as A and C five times as long as A. These samples were mixed with 1% Portland cement and their tens. strengths tested, giving the following values:

	24 hrs.	48 hrs.	3 days	7 days	28 days
A	10.0	13.0	14.0	19.0	30.0
B	18.0	20.5	21.5	25.5	35.5
C	22.0	24.0	25.0	34.0	39.5

H. G. SCHURECHT

Cement

75. The effect of mineral oils on cement. A. GUTTMANN. *Tonind. Ztg.*, **44**, 1116 (1920).—The effect of mineral oils on the strength of concrete was investigated and the following results obtained:

	Air		Petroleum oil		Coal tar oil	
	28 days	6 mos.	28 days	6 mos.	28 days	6 mos.
C	210	192	168	185	160	158
K	287	272	242	252	216	249
B	262	288	193	238	191	189

It was found that those cements into which the oil had penetrated the furthest were weakened the most. He therefore suggests the addition of a material which would make the cement impervious to liquids as a means of making Portland cement resist. to mineral oils.

76. **Plaster of paris brick.** ANON *Tonind. Ztg.*, **44**, 1259(1920).—Brick are made with ashes, sawdust, etc. using plaster of paris as a binder. 1 part plaster, 3 parts ashes and 1.5 parts water make strong brick. 150–210 are made at once by pouring the mixt. in molds. 3000 brick may be made by 2 men in 8 hrs. These brick have a crushing strength of 30 kg./ cm^2. In order to retard the setting about $^1/_4$ the volume of lime is added. H. G. SCHURECHT

77. **Plastic gypsum plaster.** WARREN E. EMLEY. *Chem. & Met. Eng.*, **24**, 740–741(1921).—When calcined gypsum is subjected to grinding under such circumstances that the water is not permitted to escape from the system, an entirely new plastic product results. Up to a certain limit the degree of plasticity seems to depend upon the duration and speed of grinding. The increased fineness of the plastic gypsum necessitates the use of more water to bring the paste to a given consistency. Yet, in spite of this excess water, the set material will average about 20 per cent stronger than that made from ordinary calcined gypsum. The process slows down the setting reaction somewhat. Samples of this plastic gypsum have been exposed to the air for four months without apparent deterioration in plasticity. It is essential that the product as it leaves the mill shall contain approximately 6.2% water. A patent, covering both the process and the product, has been applied for, and, if granted, will be given to the public for free use of any one in the United States. H. F. S.

78. **Outline of the process of lime manufacture.** ANON. *Lime*, Brief No. **250**, Nat. Lime Assoc., Washington, D. C. A four page pamphlet consisting of a detailed flow sheet with brief explanation. ED.

BOOK REVIEWS

79. **Modern brickmaking.** By ALFRED B. SEARLE. 2nd. Edition, revised and enlarged, April 1920, pp. x + 500 with 310 figs. G. Scott, Greenwood & Son, London.—A general treatise on brick making practices in England; only slightly analytical in discussion of methods, appliances and practices, and suggestive of possible ways of progress in the art. Except for some editing, and a few additional catalog cuts of machinery and a chapter of doubtful value on "The selection of a process and plant for making brick" this edition does not differ materially from the first one. There is nothing in the book that can be said to be an addition to present day knowledge of brick making.

R. C. PURDY

ACTIVITIES OF THE SOCIETY

Actions of the Board of Trustees

July 11. It was voted to accept the contract drawn up by President Pence with Ross C. Purdy, engaging the latter as Organizing Secretary for the remainder of the year 1921, and General Secretary for 1922.

The appointment of Mr. E. T. Montgomery as Chairman of the White Wares Division was confirmed.

The appointment of Mr. F. L. Steinhoff as Chairman of the Committee on Co-operation was confirmed.

Necrology

Wm. G. Hipp was born in Bolivar, Ohio, July 20th, 1860. In 1865 he moved to Canton where he lived with his parents completing his Public School education and moved to Pittsburgh in 1886. Here he became associated with the Massillon Stone and Fire Brick Company as Secretary and General Manager. In 1888 he moved to Massillon to take charge of the factory at that place. Mr. Hipp was connected with the Massillon Company from the above date until his death. The product of this concern under his management was largely confined to paving brick until 1902 when the Massillon Stone & Fire Brick Company discontinued the manufacture of paving brick and took up the manufacture of refractories. His work in this field had always been very progressive and a large portion of his time was devoted to research. He was successful in developing a special refractory product which is well known throughout the country. His most recent accomplishment was the development of Alumite products, the manufacture of which is being carried on by the Massillon Refractories Company, a concern organized by Mr. Hipp two years ago for the exclusive manufacture of these products. He was its president. The plant was just completed and in production when Mr. Hipp's death occurred on April 2nd, after one week's illness from pneumonia. He enjoyed a very wide acquaintance with the refractory trade and was highly esteemed by all who knew him. His research work, embodying the betterment of refractory products in general, was always foremost with him. His associates and the industry have lost a valuable worker. He was an active member of the American Ceramic Society from 1900 until his death. Interment was made at Westlawn cemetery, Canton, Ohio.

Preparation of Abstracts

Every article in THIS JOURNAL is to be preceded by an abstract prepared by the author and submitted by him with the manuscript. The abstract is intended to serve as an aid to the reader by furnishing an index and brief summary or preliminary survey of the contents of the article; it should be suitable for reprinting in an abstract journal so as to make a reabstracting of the article unnecessary. The abstract should, therefore, **summarize all new information completely and precisely.** Furthermore, in order to enable a reader to tell at a glance what the article is about and to enable an efficient index of its subject matter to be readily prepared, the abstract should contain **a set of subtitles** which together form a **complete and precise index** of the information contained in the article. This requires at least one and often several subtitles even for a short abstract.

In the preparation of abstracts, authors should be guided by the following rules, which are illustrated by the abstracts in THIS JOURNAL for February and March, 1921.* The **new information** contained in an article should first be determined by a careful analysis; then the subtitles should be formulated; and finally the text should be written and checked.

Rules

1. **Material not new** need not be analyzed or described in detail; a valuable summary of a previous work, however, should be noted with a statement indicating its nature and scope.

2. **The subtitles should together include all the new information;** that is every measurement, observation, method, improvement, suggestion and theory which is presented by the author as new and of value in itself.

3. **Each subtitle should describe the corresponding information so precisely** that the chance of any investigator being misled into thinking the article contains the particular information he desires when it does not, or vice-versa, may be small Such a title as "A note on blue glass," for example, is evidently too indefinite a description of information regarding "Absorption spectra of glass containing various amounts of copper-cobalt and chromium-cobalt." General subtitles, such as "Purpose" and "Results" should not be employed as they do not help to describe the specific information given in the article.

4. **The text should summarize the authors' conclusions and should transcribe numerical results of general interest,** including those that might be looked for in a table of physical and chemical constants, with an indication of the accuracy of each. It should give all the information that anyone, not a specialist in the particular field involved, might care to have in his note book.

5. **The text should be divided into as many paragraphs** as there are distinct subjects concerning which information is given, but no more than necessary. All parts of subtitles may be scattered through the text but the subject of each paragraph, however short, must be indicated at the beginning.

6. **Complete sentences** should be used except in the case of subtitles. The abstract should be made as readable as the necessary brevity will permit.

7. The ms. of all abstracts must be typewritten and double or triple spaced.

* The rules were prepared by the Research Information Service of the National Research Council. The Society is indebted to Dr. G. S. Fulcher of the Corning Glass Works (formerly with the National Research Council) for the rules and the illustrative abstracts.

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JOURNAL

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A monthly journal devoted to the arts and sciences related to the silicate industries.

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Vol. 4 September, 1921 No. 9

EDITORIAL

RESEARCH AND A PROTECTIVE TARIFF

There has recently come to the editor's desk a set of pamphlets issued by the United States Tariff Commission entitled "Tariff Information Surveys." The material contained in these pamphlets has been collected for the use of the committees of Congress in the preparation of tariff schedules. The information given is intended to represent a condensed and up-to-date account of the conditions in the various industries, as regards the nature and supplies of raw materials, manufacturing processes, labor, capital, transportation, domestic and foreign markets, costs, imports and exports, competition, tariff history, duties in foreign countries, and in general, all information which might have a bearing upon tariff schedules.

In the pamphlet dealing with clays and earths, occurs the following statement:

"It is doubtful if domestic kaolin can entirely replace the imported product, unless the quality of the domestic material improves, either through the discovery of new high-grade deposits or improved systems of purifying and standardizing the product now being mined. Increased duties might not result in immediate reduction of imports but would undoubtedly stimulate research work on the part of domestic consumers to the end that, eventually, a larger percentage of domestic kaolin would be used in the pottery and paper trades."

This statement raises a subject which we do not recall ever having seen discussed, namely the possible effects of a protective tariff upon the development of scientific research. The point of view adopted in the statement quoted, could not be safely generalized without some qualification. In some industries the creation of a protective duty, especially one which was restricted to a definite and not too long period of years, might very likely serve as a powerful stimulant to scientific research. This would most probably be the result in an industry where the value of scientific research was understood and appreciated.

On the other hand, it seems equally, or more, probable that the opposite policy might be even more effective. If the industries of the country were given to understand that no tariff protection would be given to any industry which refused or neglected to maintain either individual or coöperative research laboratories, adequately staffed and equipped for the prosecution of scientific research in the direction of lower costs, new and improved products, safer and better working conditions, increased knowledge of all factors entering into the industry,—in a word *continuous progress*, it is at least probable that the stimulating effect upon the research work of the country would be far greater. The second policy would have the further advantage that those industries which took advantage of it in order to secure tariff protection, would eventually find themselves in a position where such protection was no longer required. We venture to express the hope that at future Congressional hearings on tariff schedules, we may find the chairman of the committee calling upon the representatives of the manufacturer not only for information as to labor and other costs, both here and abroad, but also for detailed information concerning the research activities of the industry.

TO AUTHORS OF PAPERS

Authors of papers intended for presentation at the St. Louis meeting of the Society are requested to submit same for publication promptly, preferably in advance of the meeting. As far as possible, dates of publication will be determined by order of receipt by the Editor.

ORIGINAL PAPERS AND DISCUSSIONS

SOME RELATIONS OF COMPOSITION TO SOLUBILITY OF ENAMELS IN ACIDS[1]

By Homer F. Staley

ABSTRACT

Review of literature.—The literature on acid resisting enamels and glasses is reviewed.

Acid resisting powers produced by different oxides.—When substituted one for another, in each case in equal percentage amounts, various oxides and minerals increased the resistance of various enamels to the action of boiling 20 per cent hydrochloric acid in the following order of effectiveness: Al_2O_3, cryolite, Na_2O, PbO, BaO, Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3. The first five mentioned were especially effective. The remainder are undesirable materials from the standpoint of acid resistance.

Effect of the enamel base.—The relative effects of the materials were the same for various base enamel compositions.

Effect of ZrO_2 and TiO_2.—ZrO_2 and TiO_2, when substituted for small amounts of SiO_2, increased the resistance of various enamels to attack by acids, ZrO_2 being most effective in this respect. The favorable action of ZrO_2 is offset by a tendency to produce excessive chipping. Rutile gives less chipping than either zirconia or silica and greater acid resistance than silica.

Best compositions.—Enamels 2, 17, 19, 26, 27, and 33 of table 1 showed resistance to action of the acid equivalent to that of the original compoitions based on the analysis of a French acid-resisting enamel. By use of the data developed in this investigation other highly acid-resisting compositions can readily be formulated.

Although the manufacture of acid-resisting enameled wares in this country is a business of considerable magnitude and of constantly increasing technical importance, very little has been published in regard to the compositions used. The little that has appeared in print says nothing in regard to the relations of

[1] Received May 27, 1921. Published by permission of the Director, Bureau of Standards.

composition of the enamels used to solubility in acids. This question is of importance in the manufacture of wares to be used in making of chemicals, explosives, and certain food products. Manufacturers of enameled wares to be used in cooking and for other purposes in which the enamel will come into contact with dilute acids are also interested in this problem. This investigation was undertaken as an attempt to discover some of these relations.

Review of Literature

Work of Various Investigators.—Edward Orton, Jr.,[1] subjected three makes of enameled automobile tags of unknown composition to the action of boiling water for eight hours, boiling one per cent sulfuric acid for 15 minutes, and to exposure to the fumes of strong hydrochloric acid for 18 hours. The relative order of resistance of the three makes of enameled ware was the same in the three tests. Boiling in dilute sulfuric acid proved the most severe, and boiling in water the next in severity. No correlation was found between the chemical resisting properties and physical strength or beauty of appearance and finish of the enamels.

J. B. Shaw[2] made a study of the effect of variation of alumina silica and boric oxide in white enamels of the type used for coating cooking wares. The samples were boiled for 15 minutes in 1 per cent sulfuric acid and in 75 per cent acetic acid. The degree of attack was determined by the loss in weight per square inch. It was found in both these tests that the solubility increased as boric oxide increased. The action of 75 per cent acetic acid was similar to, but much less marked than, that of one per cent sulfuric acid.

In a second investigation of some white enamels for sheet steel Shaw[3] tested the enamels with lemon juice, a 10 per cent solution of citric acid and a 10 per cent solution of oxalic acid. The solutions were dropped on to the enamel surface and allowed to remain for periods of 10 minutes, 30 minutes, or until they evaporated to dryness. The degree of attack was judged by the ap-

[1] *Trans. Am. Ceram. Soc.*, **11**, 320–341 (1909).

[2] *Ibid.*, **12**, 463–494 (1910).

[3] Bur. Standards, *Tech. Paper*, No. **165**, 81–85.

pearance of the enamel. The author states that it was not possible to arrange the compositions in logical sequence, but draws the following conclusions, in which he considers the appearance of an "irridescent stain" followed by a loss of gloss or the appearance of a rough surface as "destruction:"

"1. Fluorine is decidedly detrimental to enamels which are subject to weak acid solutions. When added to enamels as fluorspar or cryolite in large or small amounts, it renders them subject to easy attack and destruction by ordinary lemon juice.

"2. Boric acid in easily fusible enamels renders them easily destroyed by weak acids, such as lemon juice, but in refractory enamels it can be used in small amounts and the enamels still maintain stability against acids. This conclusion is substantiated by the Pyrex and other chemical glasswares now on the market.

"3. No enamel of the borosilicate type made in this series was found proof against 10 per cent citric acid.

"4. Enamels containing no fluorine or boric acid can be easily made proof against citric acid, but it was not possible to reduce their refractoriness to a sufficiently low point to make them satisfactory as white enamels."

R. D. Landrum[1] tested 10 white enamels on sheet steel cooking utensils, including among the tests boiling to dryness 20 per cent acetic acid in small dishes. The amount of attack was gauged by the loss in weight. Owing to the wide variations in composition the author did not draw any conclusions from the acid tests. It is noteworthy that the compositions of several of the most resistant enamels were high in sodium oxide. There was no parallelism between chemical and physical excellence.

Action of Various Acids on Enamels.—The relative action on a given enamel of different acids and of various concentrations of the same acid has been studied by several investigators. R. D. Landrum[2] found that with acetic acid maximum attack occurred with a concentration of 20 per cent . The action of highly concentrated acids was almost negligible. E. P. Poste[3]

[1] *Trans. Am. Ceram. Soc.*, **14**, 489–509 (1912).

[2] *Ibid.*, **13**, 494–501 (1911).

[3] *Ibid.*, **17**, 137–149 (1915); **18**, 762–766 (1916); This Journal, **2**, 32–43 (1919); **3**, 560–567 (1920).

determined the action on grains of enamel of acetic, citric, tartaric, hydrochloric, nitric and sulfuric acids. The results obtained were similar to those of Landrum. All the acids had their greatest solvent action at concentrations between 10 and 30 per cent. In the last citation he states also that a weak solution of citric acid impairs the gloss of some commerical enamels.

L. E. Frost[1] conducted tests with acetic acid upon finished enameled surfaces. He obtained results that checked those of Landrum and Poste.

The present writer[2] has shown that the degree of attack of the various acids and the various concentrations of the same acids used by Poste and Landrum was proportional to the hydrogen ion concentration in the various solutions. With all the acids used the ion concentration is low in dilute solutions, increases rapidly up to concentrations between 20 and 30 per cent of acids, then decreases gradually and becomes practically zero in highly concentrated acid solutions.

Action of Acids on Glass.—Since enamels are essentially glasses, the action on glass is of interest. The literature of this subject is reviewed at some length with reference to certain types of glass by Hovestadt.[3] In brief it has been found that in lime soda glasses with high silica (over 70 per cent SiO_2) the attack by acids is less than by pure water and diminishes with increased concentration of acid. The explanation given is that with water the effect on the glass is due primarily to the solution of alkali from the glass, and secondarily to the further action on the glass of the alkali thus set free, but acid if present neutralizes the alkali as fast as it is dissolved from the glass and thus presents the secondary attack. Compositions such as are described above are not suitable for enamels.

On the other hand the relative action of water and acid was found to be completely reversed from the above when it came to treatment of low silica glasses, such as high lead glasses and com-

[1] This Journal, **1**, 422–428 (1918).

[2] Staley, Homer F., *Trans. Am. Ceram. Soc.*, **13**, 499 (1911); and **17**, 144–147 (1915).

[3] "Jena Glass," by H. Hovestadt; trans. by J. D. and Alice Everett, MacMillan and Co.

plex borosilicates. Water has little effect on such glasses, but they are attacked directly by acids, especially by hydrochloric. These compositions are of the type of glasses used for enamels and from the work of many investigators there seems to be no doubt that enamels are attacked directly by acids.

One important point treated briefly in the above mentioned review is that while calcium oxide gives glasses high resistance and sodium oxide low resistance to the attack of water, when it comes to attack by acids, calcium silicates are more readily attacked than sodium silicates.

Because of the contradictory results obtained by these various investigators and because of the lack of data on the solubilities in acid of the so-called acid resistance ware, a study of this type of enamel was deemed advisable. It was the desire of the author to develop enamels which could approach the French type in acid resistance and at the same time to gather information that would be helpful to enamelers as to the general effects of various oxides and minerals in the enamels on the solubilities of their products.

Experimental

The cover coat enamel of high grade, French, acid-resisting enamel served as the basis for the present investigation. The analysis in round numbers was as follows: SiO_2, 68; B_2O_3, 7; Na_2O, 19; CaO, 6; and is given as Enamel 1 in table 1. With this composition as a basis some seventy enamels were compounded by the method of calculated percentage composition melted.[1] In making the calculations all chemicals were considered pure and no fluorine was supposed to be lost.

TABLE 1

Composition of enamels with results of tests with boiling 20% hydrochloric acid. The letter "s" indicates that the enamels failed by softening. The letter "c" indicates that the enamels failed by chipping. The plus mark (+) indicates that the enamels could have endured the acid test longer if they had not failed by chipping, or after 1000 hours if the tests had not been discontinued.

No.	Composition in percentages SiO_2	B_2O_3	Na_2O			Hours endurance	Type of failure
1	68	7	19	6	CaO	1000+	
2	68	7	19	6	ZnO	1000+	
3	68	7	11	14	ZnO	N.G.	chipped

[1] For method see Bur. Standards, *Tech. Paper*, No. **142**, p. 70.

TABLE I (*Continued*)

No.	Composition in percentages SiO_2	B_2O_3	Na_2O				Hours endurance	Type of failure
4	68	15	3	14	ZnO		N.G.	chipped
5	76*	11	2.5	10.5	ZnO		N.G.	chipped
6	ground coat							
7	ground coat							
8	68	15	11	6	ZnO		N.G.	blistered
9	68	11	11	10	ZnO		N.G.	blistered
10	68	13	7	12	ZnO		N.G	blistered
11	73*	11	6	10	ZnO		N.G.	blistered
12	60	15	19	6	ZnO		See No. 37	
13	60	7	19	14	ZnO		89	s
14	60	23	11	6	ZnO		See No. 36	
15	60	15	11	14	ZnO		See No. 42	
16	60	7	19	14	CaO		15	s
17	60	7	19	14	BaO		1000+	
18	68	7		6	ZnO	19 Li_2O	657	s
19	60	7	19	14	PbO		1000+	
20	60	7	19	14	Al_2O_3		N.G.	blistered
21	60	7	19	14	SrO		28	s
22	60	7	19	14	MgO		N.G.	blistered
23	60	21	19				14	s
24	60	14	19	7	Al_2O_3		26?	s
25	60	14	19	7	MgO		14	s
26	60	7	12	14	PbO	7 BaO	1000+	
27	60	7	12	7	PbO	14 BaO	1000+	
28	60	7	12	14	PbO	7 Al_2O_3	677+	c
29	60	7	14	14	PbO	7 CaO	344+	c
30	not made							
31	not made							
32	60	7	19	14	CaF_2		172	s
33	60	7	19	14	Cryolite		1000+	
34	67	14	12	7	ZnO		infusible	
35	60	14	12	7	ZnO	7 Al_2O_3	42	s
36	60	21	12	7	ZnO		3	s
37	60	14	19	7	ZnO		5	s
38	60	14	12	7	ZnO	7 CaO	3	s
39	60	14	12	7	ZnO	7 MgO	5	s
40	60	14	12	7	ZnO	7 BaO	5	s
41	60	14	12	7	ZnO	7 SrO	3	s
42	60	14	12	14	ZnO		3	s
43	60	14	12	7	ZnO	7 PbO	5	s
44	60	14	12	7	ZnO	7 Li_2O	3	s
46	60	14	12	7	PbO	7 TiO_2	5	s

* SiO_2 replaced by feldspar.

TABLE I (*Continued*)

No.	Composition in percentages SiO₂	B₂O₃	Na₂O				Hours endurance	Type of failure
47	not made							
48	60	14	12	7 PbO	7 Al_2O_3		146	s
49	60	14	19	7 PbO			313?	s
50	60	14	12	7 PbO	7 CaO		3	s
51	60	14	12	7 PbO	7 MgO		5	s
52	60	14	12	7 PbO	7 BaO		5	s
53	60	14	12	7 PbO	7 SrO		3	s
54	60	14	12	7 PbO	7 ZnO		3	s
55	60	14	12	14 PbO			34	s
56	60	14	12	7 PbO	7 CaF_2		3	s
57	60	14	12	7 PbO	7 cryolite		48	s
58	60	14	12	7 PbO	7 Li_2O		5	s
59	53	14	12	7 PbO	7 TiO_2	7 Al_2O_3	335	s
60	53	14	19	7 PbO	7 TiO_2		241	s
61	53	14	12	7 PbO	7 TiO_2	7 BaO	48	s
62	53	14	12	7 PbO	7 TiO_2	7 ZnO	3	s
63	53	14	12	14 PbO	7 TiO_2		48	s
64	53	14	12	7 PbO	7 TiO_2	7 CaF_2	3	s
65	53	14	12	7 PbO	7 TiO_2	7 cryo.	301	s
66	53	14	12	7 PbO	7 TiO_2	7 Li_2O	5	s
67	53	14	12	7 PbO	7 ZrO_2	7 Al_2O_3	106+	c
68	53	14	19	7 PbO	7 ZrO_2		106+	c
69	53	14	12	7 PbO	7 ZrO_2	7 BaO	82+	c
70	53	14	12	7 PbO	7 ZrO_2	7 ZnO	58+	c
71	53	14	12	14 PbO	7 ZrO_2		136+	c
72	53	14	12	7 PbO	7 ZrO_2	7 CaF_2	44	s
73	53	14	12	7 PbO	7 ZrO_2	7 cryo.	386	s
74	53	14	12	7 PbO	7 ZrO_2	7 Li_2O	44	s

The enamels were melted in two kilogram batches in crucibles until bubbling ceased and were then quenched by being poured into cold water. The resultant glasses were dried and ground to powder in ball mills. The test specimens were oval bottomed cast iron cups. These were coated with a rather refractory ground coat, which contained two frits, W-6 and W-7:

W-6 Frit

Flint	350
Borax	185
Sodium nitrate	35
Red lead	41

W-7 Frit

Flint	519
Borax	345
Litharge	37

The mill batch was as follows:

W-6 Frit	250
W-7 Frit	369
Flint	172
Clay	112
Cobalt oxide	1.2
Water	600

Grind to pass an 80-mesh sieve

The temperature of firing of the ground depended on the particular cover enamel being applied, and ranged from 800°C to 950°C with corresponding decreases in the time from 18 minutes to three minutes. The cover enamel took considerably less time in each case, this varying from 10 minutes to about 45 seconds. The size and thickness of the iron casting and type of furnace have such great effects on the time and temperature of firing that it is impossible to give data which will have a direct relation to actual commercial conditions. It is well to note, however, that some of the refractory compositions gave best results at lower temperatures with a long firing period, as the enamels were so viscous that it was necessary to drive off all gas and entrapped air previous to fusing of the enamel.

The powdered cover enamel was applied by sifting in the manner commonly used for making cast iron enameled wares by the dry-powder process. In most cases it was necessary to make two applications of cover enamel in order to get a coating of sufficient uniformity of thickness. The enameled cups cooled normally upon removal from the furnace. There was no apparent development of crazing in any of the enamels.

Twenty per cent hydrochloric acid was chosen for testing the acid resistance of the enamels. A mineral rather than an organic acid was selected because the former appears to be more destructive on the types of compositions used, which was also the case with those tested by other investigators mentioned in the introduction of the paper. Hydrochloric was selected in preference to sulfuric acid because the latter forms insoluble compounds with several of the constituents used in this series of enamels. Hydrochloric acid is preferable to nitric for testing purposes, for while a nitric acid solution constantly changes in composition when boiled, a twenty per cent hydrochloric acid solution remains constant in composition.

The acid resistance tests were made by placing the cups on a steam bath and keeping them filled with the acid solution for a period of 1000 hours unless the enamel failed before that time. In order to avoid an accumulation of salts in the cups, they were washed out and filled with entirely new acid solution every seven hours.

It is questionable whether the loss of weight of an enamel surface is a true criterion of the degree of attack by the acid. In some cases an enamel will take up radicals from the acid solution and actually increase in weight while it is undergoing disintegration. Moreover, in the present investigation this method was out of the question because of the progressive chipping of the enamel coating that took place with many compositions and because of the progressive oxidation and scaling of the exterior of the cups. The first impairment of the lustre of the enamel surface is not a true indication of lack of resistance to acids, for many enamels will undergo this impairment of lustre and then resist the action of acid solutions indefinitely.

E. P. Poste[1] has well described the difference of surface appearance of an enamel produced by different degree of acid action, as follows:

"If the action is very slight a peculiar surface discoloration develops to a loss of gloss and a lighter color. The surface can be definitely scratched with a knife. As the action again increases, the more soluble constituents of the enamel go into solution, and leave behind a very fine, white powder which can be rubbed off when the surface is dry. This condition is termed 'chalking' and indicates a very severe action."

Since we wished to determine the point at which the enamel coating would be no longer suitable for use in chemical apparatus, where there is the possibility of a certain amount of mechanical as well as chemical action, we took as the point of failure the time at which the surface of the enamel had softened sufficiently to permit of being definitely scratched with a pointed knife blade. A few simple tests showed that the variations of results due to different operators and different knife

[1] *Trans. Am. Ceram. Soc.*, 19, 150 (1917).

blades were not sufficiently great to disturb the relative order of resistance of the various enamels tested. While the method is admittedly crude, it conforms to the method by which acid-resisting wares are condemned in use. Fortunately for our work the various oxides and minerals used had either a definitely beneficial or detrimental effect on acid resistance in the range of variations we employed, and, therefore, by making cross-comparisons we were able to determine rather accurately for the type of compositions used, the relative effect of the various oxides and minerals on acid resistance.

The calculated composition of the various enamels and the results of the tests are shown in table 1. In this table the letter "s" indicates that the enamel failed by softening; the letter "c" indicates that the enamel failed by chipping, the plus sign after certain figures for hours of endurance indicates that as far as resistance to acids was concerned the sample could have endured the acid treatment for a longer time.

Discussion of Results

It is possible to rearrange the data shown in table 1 in various tables in any one of which the compositions will differ from each other only by one variable portion. Examples of the many possible arrangements illustrating the effect of oxides and radicals other than SiO_2, TiO_2 and ZrO_2 are shown in tables 2 to 8. A summary of these tables is given in table 9.

TABLE 2

Constant portion: 60 SiO_2, 7 B_2O_3, 19 Na_2O.
Variable portion: 14 parts.

No.	Variable	Hours endurance	Type of failure
35	Cryolite	1000+	
19	PbO	1000+	
17	BaO	1000+	
32	CaF_2	172	Softening
13	ZnO	89	Softening
21	SrO	28	Softening
16	CaO	15	Softening
23	B_2O_3	14	Softening

TABLE 3

Constant portion: 60 SiO_2, 14 B_2O_3, 12 Na_2O, 7 ZnO
Variable portion: 7 parts

No.	Variable	Hours endurance	Type of failure
35	Al_2O_3	42	Softening
37	Na_2O	5	Softening
43	PbO	5	Softening
40	BaO	5	Softening
39	MgO	5	Softening
42	ZnO	3	Softening
41	SrO	3	Softening
38	CaO	3	Softening
36	B_2O_3	3	Softening

TABLE 4

Constant portion: 60 SiO_2, 7 B_2O_3, 12 Na_2O, 14 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
28	Al_2O_3	677+	Chipping
19	Na_2O	1000+	
26	BaO	1000+	
29	CaO	345+	Chipping
55	B_2O_3	34	Softening

TABLE 5

Constant portion: 60 SiO_2, 7 B_2O_3, 12 Na_2O, 7 BaO, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
26	PbO	1000+	
27	BaO	1000+	
52	B_2O_3	5	Softening

TABLE 6

Constant portion: 53 SiO_2, 7 TiO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
59	Al_2O_3	335	Softening
65	Cryolite	301	Softening
60	Na_2O	241	Softening
63	PbO	48	Softening
61	BaO	41	Softening
66	Li_2O	5	Softening
64	CaF_2	3	Softening
62	ZnO	3	Softening

TABLE 7

Constant portion: 53 SiO_2, 7 ZrO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
67	Al_2O_3	106+	Chipping
73	Cryolite	386	Softening
68	Na_2O	106+	Chipping
71	PbO	136+	Chipping
69	BaO	82+	Chipping
74	Li_2O	44	Softening
72	CaF_2	42	Softening

TABLE 8

Constant portion: 60 SiO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.
Variable portion: 7 parts.

Number	Variable	Hours endurance	Type of failure
48	Al_2O_3	146	Softening
57	Cryolite	48	Softening
49	Na_2O	313?	Softening
55	PbO	34	Softening
52	BaO	5	Softening
58	Li_2O	5	Softening
51	MgO	5	Softening
56	CaF_2	3	Softening
54	ZnO	3	Softening
53	SrO	3	Softening
50	CaO	3	Softening

TABLE 9

Summary of results in Tables 2–8.

Results are stated in hours endurance. The plus sign (+) following 1000 (thus 1000+) indicates that the sample did not fail in 1000 hour's test. In other cases the sign indicates that the sample failed by chipping before it softened sufficiently to be scratched.

Variable	2	3	4	5	6	7	8
Al_2O_3		42	677+		335	106+	146
Cryolite	1000+				301	386	48
Na_2O		5	1000+		241	106+	
PbO	1000+	5		1000+	48	136+	34
BaO	1000+	5	1000+	1000+	41	82+	5
Li_2O					5	44	5
MgO		5					5
CaF_2	172				3	42	3
ZnO	89	3			3		3
SrO	28	3					3
CaO	15	3	345+				3
B_2O_3	14	3	34	5			

TABLE 10

Comparison of effects of ZrO_2 (table 7), TiO_2 (table 6), and SiO_2 (table 8).

Constant portion: 53 SiO_2, 14 B_2O_3, 12 Na_2O, 7 PbO.

Variable portion: 7 parts series, 7 parts group.

Results are stated in hours endurance. The + sign indicates that the sample failed by chipping.

Series variable	Group variable						
	Al_2O_3	Cryolite	Na_2O	PbO	BaO	Li_2O	CaF_2
ZrO_2	106+	386	106+	136+	82+	44	42
TiO_2	335	301	241	48	41	5	3
SiO_2	146	48	34	5	5	5	3

It was not possible to show the effect of all the oxides in any one series on account of the wide variation of the effect of these on chipping and acid resistance. In series with a refractory glass base, many of the oxides caused excessive chipping (see table 7). In series with a fusible glass base the resistance to acids was so low in many cases that comparison was difficult (see table 3). The use of various base glasses and cross references is an advantage in that it enables us to determine whether the relative effect of the various materials is the same in different enamels.

These tables show that when substituted for one another in equal percentage amounts, the various materials affected the resistance of the enamels to acids in the following order, the most advantageous being named first: Al_2O_3, cryolite (Na_3AlF_6), Na_2O, PbO, BaO, Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3. This order of effect is found in all tables with the exception of the position of sodium oxide in table 8. The endurance of this particular enamel (number 49) was entirely out of proportion to that of other very similar compositions, and there is little doubt that there is some error in the record. The only other case of a doubtful record among all the enamels tested is that of number 24. In this case the endurance is too low.

The oxides and minerals fall into two rather distinct groups, one of which contains materials having a decidedly favorable effect on acid resistance when substituted for others in the list, the other containing materials having an unfavorable effect. In the group of desirable materials are: Al_2O_3, cryolite, Na_2O, PbO, BaO. In the group of undesirable substitutes are: Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3.

The presence of cryolite in the groups of favorable substitutes is rather remarkable, for according to J. B. Shaw[1] addition of cryolite has detrimental effect on the acid resistance of enamels. However, it must be remembered that we are speaking here of the effect of substitution of cryolite for other materials in equal percentage amounts. Shaw was writing of the addition of fluorine to an enamel formula, which would decrease the percentage of all the other ingredients, including silica, in the enamel. The position of cryolite in our results is established by its place in four series of enamels. That the fluorine was not volatilized from the composition during smelting was shown by the fusibility of the enamels and also by the fact that 6.3 per cent fluorine was found in the melted enamel. It may be added that the cryolite-bearing enamels could be given slight scratches at the beginning of the acid tests but afterward became more resistant.

The presence of Na_2O in the group of favorable oxide substitutes and of ZnO and CaO among the unfavorable ones is also contrary to current assumptions in regard to resistance of glass to chemical action. As pointed out in the discussion of the action of acids on glass, the types of compositions used for making glasswares are high in silica and are attacked by water more than by acids. In the case of soft glasses, such as were used for enamels in this investigation, there is a direct attack of the glass by acids and relations of composition to resistance may be entirely different in the two cases. Zinc oxide is a common constituent of chemical glasswares[2] but these are so high in silica that the qualitative differences in effect of the basic oxides are negligible. Sodium oxide has another decided advantage over zinc and calcium oxides in that it produces more fusible glasses and, therefore, permits the use of a higher percentage of silica than either zinc oxide or calcium oxide. In fact, it is rather difficult to make a highly acid resistant enamel without the use of considerable sodium oxide. The presence of a high percentage of Na_2O in the French enamel, used as the basis of the series of enamels, and its place near the top of four series of enamels made by us, fixes its standing rather definitely.

[1] Bur. Standards, *Tech. Paper,* No. **165**, p. 84.

[2] Bur. Standards, *Tech. Paper,* No. **107**, p. 8.

The effects of substituting ZrO_2 and TiO_2[1] for SiO_2 are shown in table 10. It will be seen that ZrO_2 gives highest resistance followed in order by TiO_2 and SiO_2. However, the substitution of seven per cent of ZrO_2 for silica caused excessive chipping. On the other hand substitution of TiO_2 made more fusible enamels and reduced chipping. The favorable action of TiO_2 is probably the reason for its use in limited quantities by most manufacturers of acid-resisting enameled wares.

Conclusions

1. When substituted one for another, in each case in equal percentage amounts, various oxides and minerals increased the resistance of various enamels to the action of boiling 20 per cent hydrochloric acid in the following order of effectiveness: Al_2O_3, cryolite, Na_2O, PbO, BaO, Li_2O, MgO, CaF_2, ZnO, SrO, CaO, B_2O_3.

The first five mentioned were especially effective. The remainder are undesirable materials from the standpoint of acid resistance.

2. The relative effects of the materials were the same for various base enamel compositions.

3. ZrO_2 and TiO_2, when substituted for small amounts of SiO_2, increased the resistance of various enamels to attack by acid, ZrO_2 being most effective in this respect.

The favorable action of ZrO_2 is offset by a tendency to produce excessive chipping. Rutile gives less chipping than either zirconia or silica and greater acid resistance than silica.

4. Enamels 2, 17, 19, 26, 27, and 33 of table 1 showed resistance to action of the acid equivalent to that of the original composition based on the analysis of a French acid-resisting enamel.

By use of the data developed in this investigation other highly acid-resisting compositions can readily be formulated.

Bureau of Standards
Washington, D. C.

[1] Rutile from American Rutile Co., 95% TiO_2, 1½% Fe_2O_3, 3.5% SiO_2

HIGH FIRE PORCELAIN GLAZES[1]

By H. H. Sortwell

ABSTRACT

Field covered.—The glazes studied covered the field 3.0 to 13.0 equivalents SiO_2 and 0.3 to 3.25 equivalents Al_2O_3 between the Al_2O_3:SiO_2 ratios of 1:4 and 1:20. The RO was maintained at 0.7 CaO and 0.3 K_2O.

Deformation temperatures.—The deformation temperatures were determined by cones in a small gas furnace heated at the rate of 50°C per hour. The deformation temperatures are shown graphically by isotherms. The results of the part of the field previously covered by Stull and Howat agree with their work. It was found that there is a deformation eutectic axis at a slight inclination to the ordinate representing Al_2O_3 up to 7.0 equivalents SiO_2. Above 7.0 equivalents the inclination rises, and at 11.0 equivalents SiO_2 it increases much more.

Firing tests.—The glazes were applied to porcelain cups biscuited at cone 08, and fired to cones 10, 12, 14 and 16. The cone 10 test was made only for comparison, since Stull and Howat had previously covered a small part of the field at cones 9 and 11.

The glazes are plotted both by empirical formulas and batch weights, showing the location of the best glazes at the different temperatures.

In agreement with Stull's statement, increase in Al_2O_3 in this type of glaze decreases crazing. Increase in SiO_2 will not decrease crazing but if carried far enough will cause crazing to occur.

From cone 12 to cone 16 the best glazes have Al_2O_3 and SiO_2 contents corresponding to the approximate formula $Al_2O_3 = 0.3 + {}^1/_{12}\ SiO_2$.

Introduction.—A great deal of material has been published on porcelains of all types, but systematic information on porcelain glazes fired at higher temperatures is more limited.

Stull[2] thoroughly covered the field for glazes maturing at cone 11. Stull and Howat[3] investigated the field at cone 9 and reported deformation temperature studies for the glazes made.

[1] Received June 29, 1921. Published by permission of the Director, Bureau of Standards.

[2] *Trans. Am. Ceram. Soc.*, **14**, 62–67 (1912).

[3] *Ibid* **16**, 454–460 (1914).

Since no detailed information was to be had on glazes of this type for high fire porcelain, chemical porcelain, spark plugs, pyrometer tubes, etc., maturing from cone 12 to cone 16, the following investigation was undertaken.

Compositions Studied.—As originally laid out the field consisted of 35 members with 3, 4, 5, 7, 9, 11, and 13 equivalents of silica, and alumina corresponding to alumina-silica ratios of 1:10, 1:8, 1:6, 1:5, and 1:4. The RO members were constant at 0.7 and 0.3 K_2O. This covered the field with fair uniformity when plotted both by the empirical formula method and by batch weights. Later, to round out the deformation tempera ture study, 15 additional glazes were made with silica 4, 5, 7, 9, 11, and 13 equivalents with the alumina-silica ratio of 1:12; silica 5, 7, 9, 11 and 13 equivalents with the alumina-silica ratio of 1:15; and silica 7, 9. 11, and 13, equivalents with the alumina-silica ratio of 1:20.

Procedure.—The glazes were weighed out separately in one kilogram batches and ground three hours in small ball mills. The materials used analyzed as follows:

	Flint	N.Carolina kaolin	Maine feldspar	Whiting
SiO_2	98.43	41.96	72.85	0.91
Fe_2O_3	.26	.52	.48	.30
Al_2O_3	.80	35.95	15.45	.34
CaO	——	.24	.31	55.02
K_2O	——	——	7.89	——
Na_2O	——	——	2.31	——
MgO	——	——	——	.44
Loss on ignition	.14	20.40	.25	43.44
	99.63	99.07	99.54	100.45

A small quantity of each glaze was evaporated to dryness and moulded into test cones for the deformation temperature determinations, which were made in a small gas furnace. The temperature was raised to 1100°C in one hour and from 1100°C on at the rate of 50° per hour. The temperature measurements were made with a platinum platinum-rhodium thermocouple and a Leeds-Northrup potentiometer indicator. Five cones were tested at a time, the thermocouple junction being within

three-eighths of an inch from each cone. Uniform temperatures were maintained within the furnace as shown by Orton cones Two or more determinations were made on each glaze, checks within 5°C being obtained.

The glazes were applied, by dipping, on porcelain cups 2½ inches in diameter, 2½ inches deep and 1/8 inch thick which had previously been biscuited to cone 08 in a slow oxidizing fire. The composition of the mixture used was as follows:

North Carolina kaolin	31
Florida kaolin	12
Tenn. ball clay No. 5	5
Flint	34
Feldspar	18

Four firing tests were made in a gas-fired kiln, to cone 10 in 20 hours, to cone 12 in 20 hours, to cone 14 in 22 hours and to cone 16 in 24 hours. Reducing conditions were maintained up to cone 8 but from that point on reduction was diminished until the fire was neutral or slightly oxidizing at the finish.

Deformation Temperatures.—The silica and alumina equivalents of all the glazes and their deformation temperatures are given in table 1. The deformation eutectic axis in the part of the field previously covered practically agrees with the work of Stull and Howat although the softening temperatures found in the present work are lower, as would be expected due to the slower rate of heating. Since the field was not covered as closely in this work, the slighter variations are not shown.

TABLE I

No.	Al_2O_3	SiO_2	$Al_2O_3 : SiO_2$	Deformation temperature, °C	No.	Al_2O_3	SiO_2	$Al_2O_3 : SiO_2$	Deformation temperature, °C
1	0.300	3.0	1:10	1173	26	1.100	11.0	1:10	1275
2	.375	3.0	1:8	1146	27	1.375	11.0	1:8	1278
3	.500	3.0	1:6	1109	28	1.833	11.0	1:6	1300
4	.600	3.0	1:5	1109	29	2.200	11.0	1:5	1350
5	.750	3.0	1:4	1134	30	2.750	11.0	1:4	1418
6	.400	4.0	1:10	1137	31	1.300	13.0	1:10	1315
7	.500	4.0	1:8	1115	32	1.625	13.0	1:8	1317
8	.666	4.0	1:6	1114	33	2.166	13.0	1:6	1336
9	.800	4.0	1:5	1124	34	2.600	13.0	1:5	1386
10	1.000	4.0	1:4	1210	35	3.250	13.0	1:4	1461

TABLE I (*Continued*)

No.	Al_2O_3	SiO_2	$Al_2O_3:SiO_2$	Deformation temperature, °C	No.	Al_2O_3	SiO_2	$Al_2O_3:SiO_2$	Deformation temperature, °C
11	0.500	5.0	1:10	1124	A_1	0.333	4.0	1:12	1175
12	.625	5.0	1:8	1157	A_2	.416	5.0	1:12	1151
13	.833	5.0	1:6	1157	A_3	.583	7.0	1:12	1148
14	1.000	5.0	1:5	1173	A_4	.750	9.0	1:12	1183
15	1.250	5.0	1:4	1223	A_5	.916	11.0	1:12	1252
16	.700	7.0	1:10	1147	A_6	1.083	13.0	1:12	1317
17	.875	7.0	1:8	1159	B_1	.333	5.0	1:15	1169
18	1.166	7.0	1:6	1208	B_2	.466	7.0	1:15	1149
19	1.400	7.0	1:5	1218	B_3	.600	9.0	1:15	1180
20	1.750	7.0	1:4	1292	B_4	.733	11.0	1:15	1230
21	.900	9.0	1:10	1209	B_5	.867	13.0	1:15	1376
22	1.125	9.0	1:8	1224	C_1	.350	7.0	1:20	1207
23	1.500	9.0	1:6	1230	C_2	.450	9.0	1:20	1237
24	1.800	9.0	1:5	1248	C_3	.550	11.0	1:20	1398
25	2.250	9.0	1:4	1370	C_4	.650	13.0	1:20	1410

The results are plotted for the molecular variations of alumina and silica (figure 1) and for the batch weights (figure 2), for which the glazes were calculated into percentages of clay, flint and fluxes (feldspar and whiting in the proportion of 167 feldspar to 70 whiting).

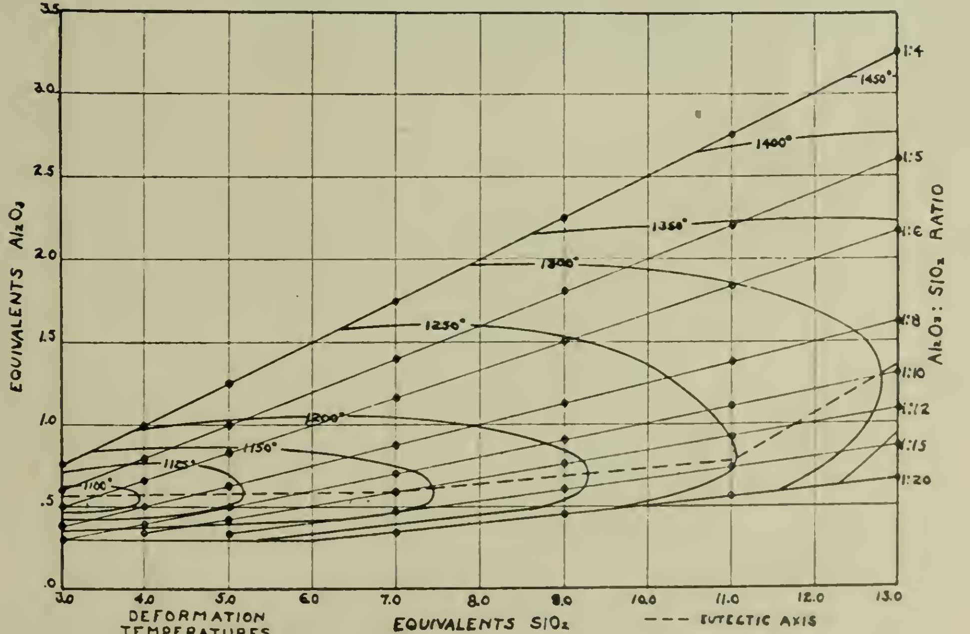


FIG. 1.

As shown in figure 1, increase in silica to 11 equivalents maintaining the alumina constant has little effect in comparison with alumina in increasing the deformation temperature as the isotherms run in the general direction of the alumina ordinate up to 11 equivalents. Beyond this figure increase in silica has a more pronounced effect on the deformation temperature.

Starting with 0.3 Al_2O_3 and any silica content, increasing the Al_2O_3 lowers the deformation temperature until the eutectic axis is crossed. Further increase in Al_2O_3 raises the deformation temperature.

The deformation eutectic axis lies at a slight inclination to the ordinate. As the silica content approaches seven equivalents, this inclination rises and at 11 equivalents it increases much more.

Examination of figure 2 shows that increasing flint does not greatly increase the deformation temperature until the composition approaches 60% flint. Further increase in flint increases the temperature rapidly.

Starting with zero clay, additions of clay first lower the deformation temperature, after which further increments of clay increase the temperature gradually until 45% clay is approached. From that point the temperature increase with increments of clay is more abrupt.

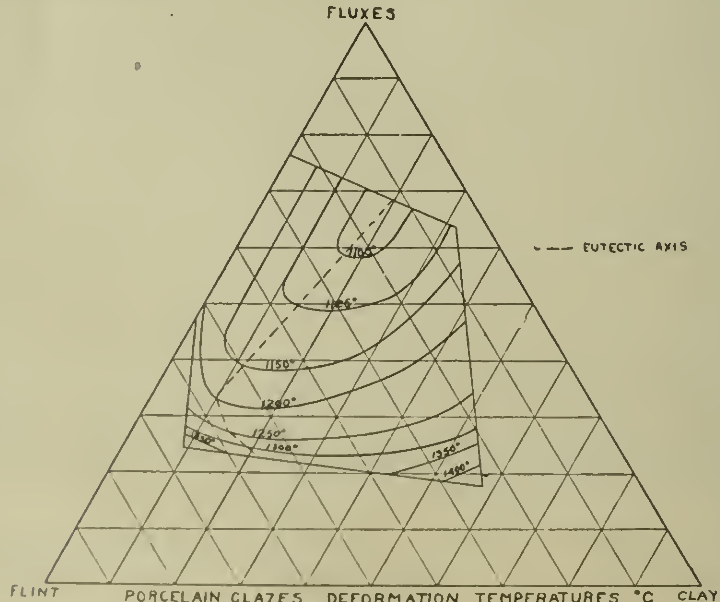


FIG. 2.

Decrease in the flux content (feldspar and whiting) increases the temperature of deformation gradually until it approaches 30%, after which further reductions cause a rapid rise in temperature.

The deformation eutectic axis starts at approximately 20% clay, 10% flint and 70% fluxes and runs in a straight line to approximately 10% clay, 55% flint and 35% fluxes. At this point the axis deflects to a higher clay content.

A plaster of Paris solid diagram was made of the field as plotted in figure 2 and is shown in figure 3. This shows plainly within what wide limits the more fusible glazes fall.

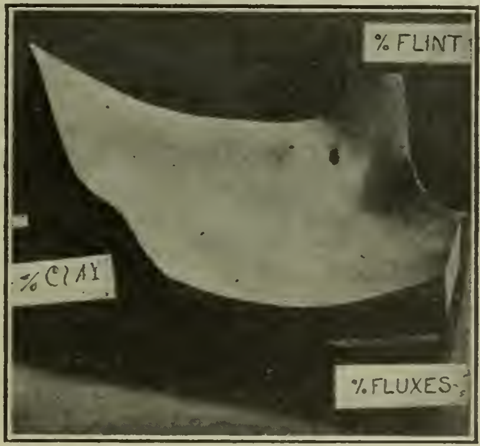


FIG. 3.

Cone 10 Firing Test.—In figures 4 and 5 are shown the results of the cone 10 firing test. At this heat treatment only a small part of the field is bright and the crazed area is comparatively large. It will be noted that there is a belt surrounding the bright area in which the glazes are of semi-mat appearance, and surrounding this are glazes of mat appearance. The latter have the characteristic mat texture due to high alumina while for the high silica glazes the term mat appearance is used only as a criterion of maturity. Outside of the mat area the glazes are dry and immature.

Figure 4 shows that the obvious way to correct crazing in this type of glaze is to increase the alumina content by addition of clay.

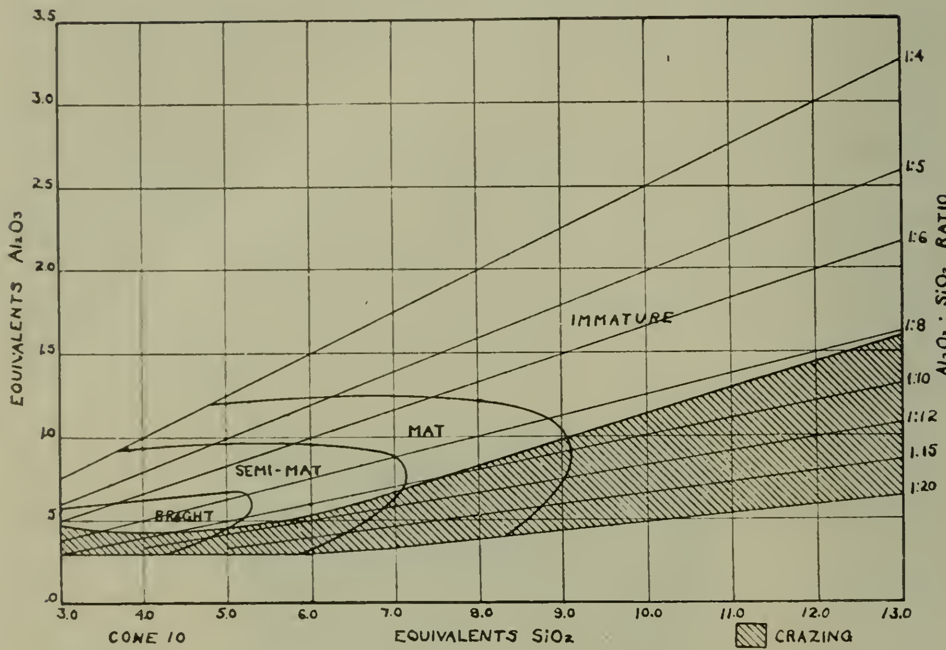

3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
EQUIVALENTS Al_2O_3
IMMATURE
MAT
SEMI-MAT
BRIGHT
1:4
1:5
1:6
1:8
1:10
1:12
1.15
1:20
Al_2O_3 : SiO_2 RATIO
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
CONE 10
EQUIVALENTS SiO_2
CRAZING

FIG. 4.

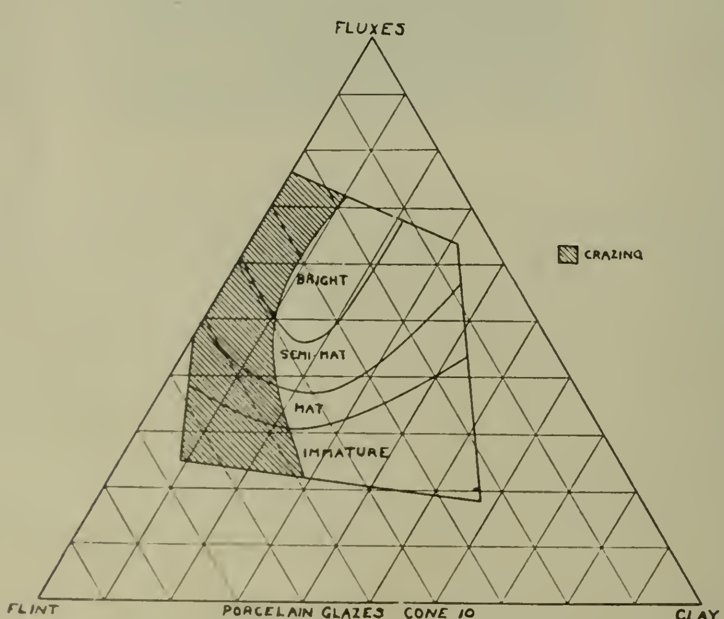

FLUXES
CRAZING
BRIGHT
SEMI-MAT
MAT
IMMATURE
FLINT
PORCELAIN GLAZES CONE 10
CLAY

FIG. 5.

Cone 12 Firing Test.—At cone 12, figures 6 and 7, the area of good bright glazes has increased and the crazing area receded as would be expected. Glazes 2, 3 and 4, show signs of overfiring as evidenced by the formation of bubbles which were not pres-

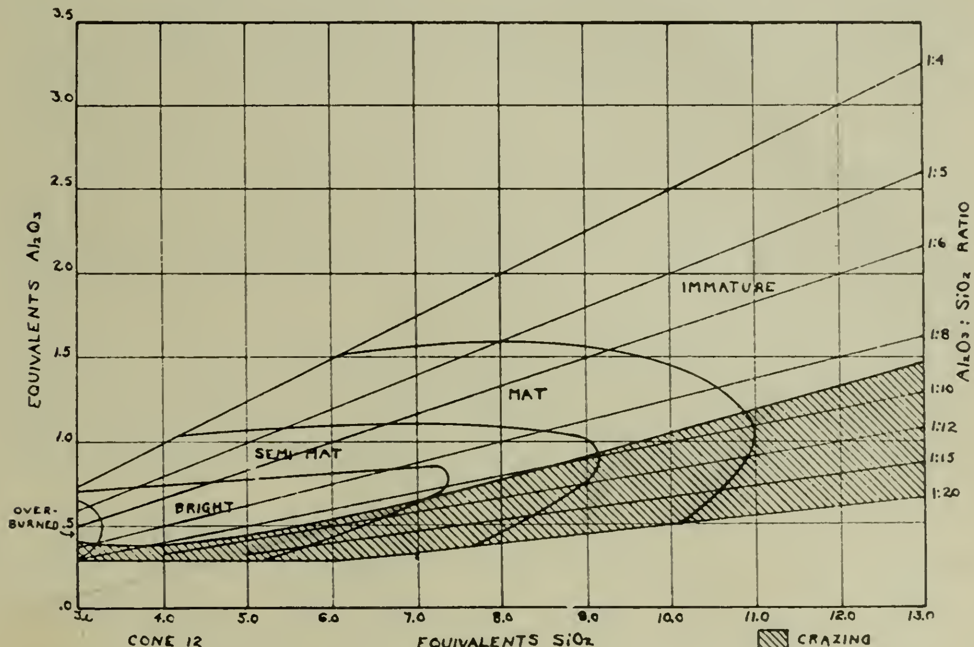


FIG. 6.

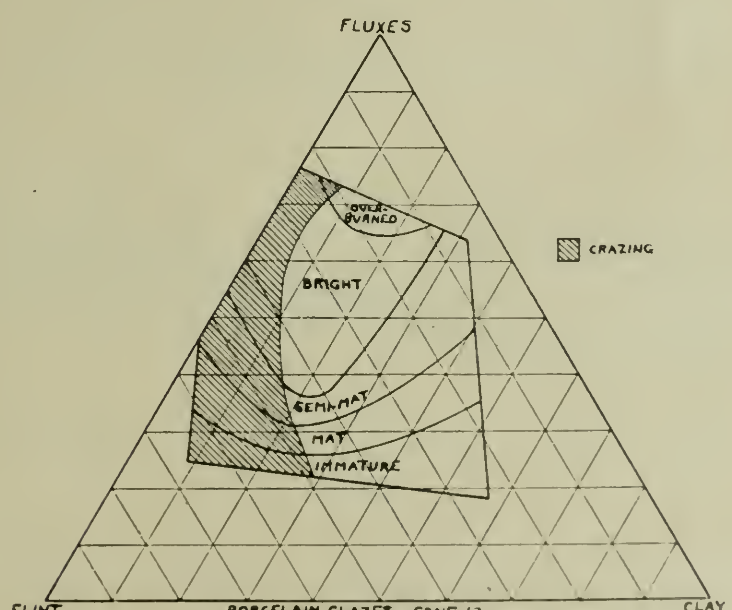


FIG. 7.

ent at cone 10. The semi-mat and mat areas have shifted position in accordance with the change in the area of bright glazes.

Glazes C_1, C_2, C_3, C_4, B_3, B_4, and B_5, which are the high silica glazes of lowest alumina content and the only glazes of 55 or more per cent flint, show signs of segregation at this temperature. This evidenced itself by lines on the surface of the glaze similar to watermarks but rising from the surface instead of being depressions. It appeared as if the fluxes were drawn to the inside of the glaze leaving a skeleton of flint at the surface. With the contraction of the test piece during firing, these high flint glazes did not follow, and consequently had to rise from the surface of the trial piece.

Cone 14 Firing Test.—Figures 8 and 9 show that at cone 14 the area of bright glazes and the area of overfired glazes has increased, the crazed area receded still further, with the semi-

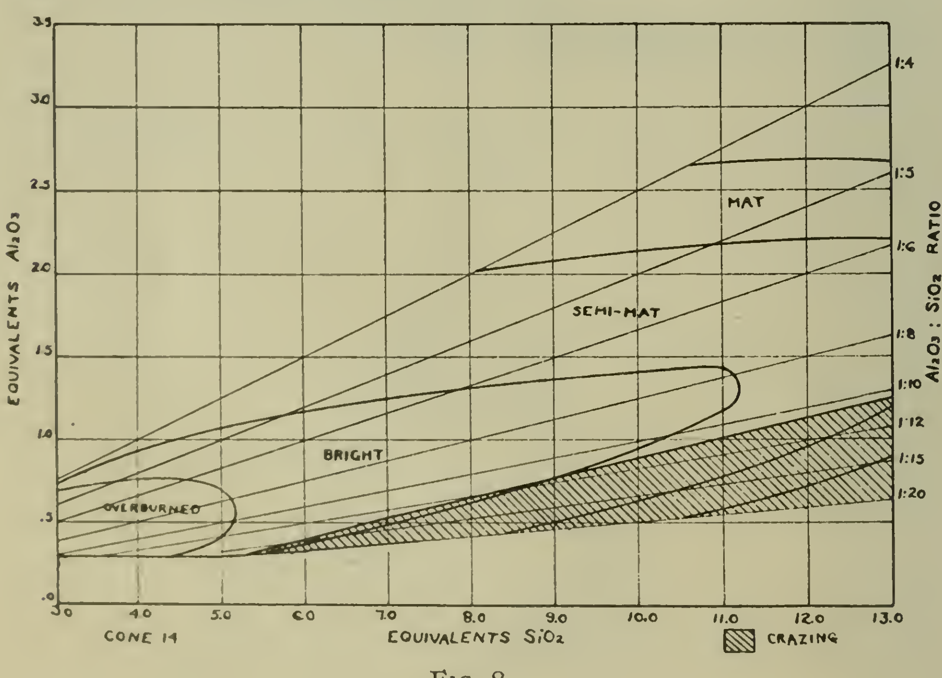


FIG. 8.

mat and mat areas shifted again. The softer of the over-fired glazes at this temperature were full of bubbles and had run to the bottom of the piece badly.

It was interesting to note that glazes 2 and 3, which were badly overfired and were far out of the craze area at this heat treatment, were crazed. No. 3 had been sound at cone 10 and cone 12. This seems to be evidence that when this type of glaze is overfired sufficiently, its composition or its physical state is changed enough to cause crazing. The 7 glazes containing 55 or more per cent of flint showed segregation as at cone 12.

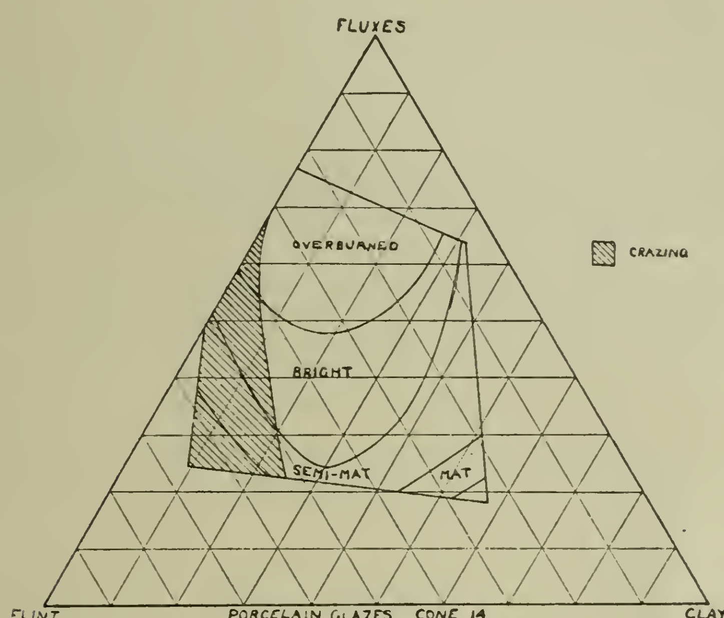


FIG. 9.

Cone 16 Firing Test.—At cone 16, figures 10 and 11, the area of bright glazes crosses the entire field, the area of overfired glazes is enlarged and the crazed area smaller. The semi-mat and mat areas have shifted in accordance with the change in the bright area.

The glazes which were overfired at cone 14 were not included in the cone 16 test so that further observation of the effect of overfiring on crazing was not available, as none of the glazes which were overfired at cone 16 but matured at cone 14 had been overfired as much as glazes 2 and 3 at cone 14. The segregation is present in the same glazes at cone 16 as at cone 14.

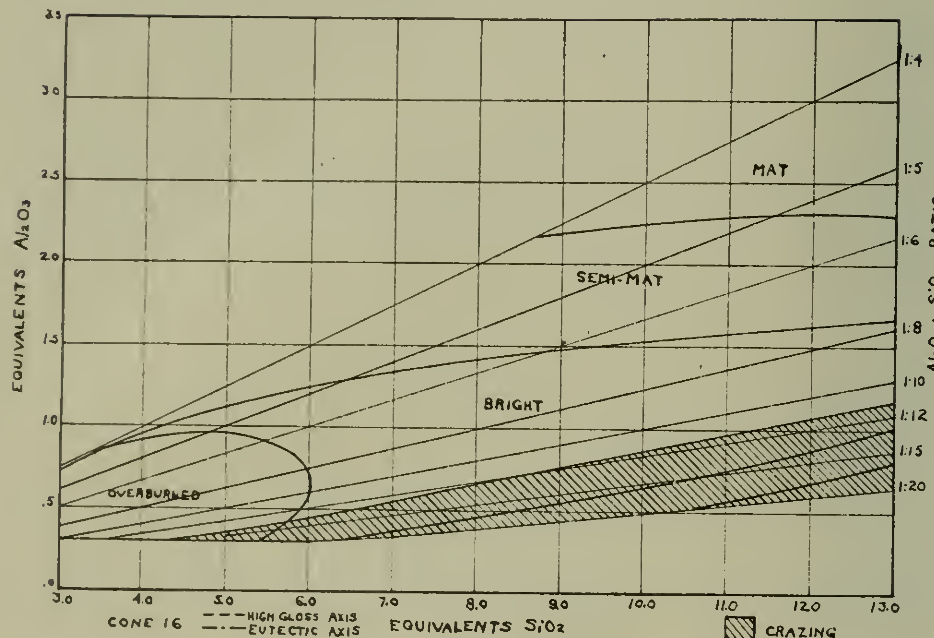

EQUIVALENTS Al_2O_3
Al_2O_3 : SiO_2 RATIO
MAT
SEMI-MAT
BRIGHT
OVERBURNED
1:4
1:5
1:6
1:8
1:10
1:12
1:15
1:20
CONE 16
--- HIGH GLOSS AXIS
-·- EUTECTIC AXIS
EQUIVALENTS SiO_2
CRAZING

FIG. 10.

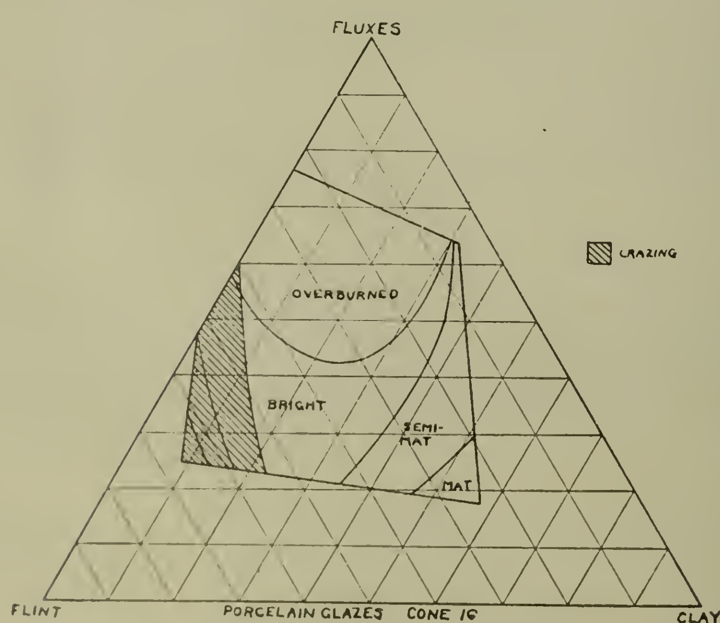

FLUXES
CRAZING
OVERBURNED
BRIGHT
SEMI-MAT
MAT
FLINT
PORCELAIN GLAZES CONE 16
CLAY

FIG. 11.

It is to be noted that although a great many of these mat glazes are such due to immaturity, as may be seen by following the charts through the successive tests, those mats and semi-mats in which the alumina silica ratio is as high as 1:4 for 3–6 equivalents of silica and as low as 1:6 at 10 equivalents of silica (see figure 10) are not mats of immaturity. Glazes 5, 10 and 15 which have lower deformation points than most of the bright glazes at cone 16 are still semi-mats. Glaze No. 5 with a deformation temperature of 1134° is still a semi-mat at cone 16.

In figure 11 the high gloss axis and the deformation eutectic axis are plotted for comparison. Except in the vicinity of 0.3 equivalents silica the best glazes of a given silica content are higher in alumina and a trifle harder than the most fusible glaze of that silica content. The eutectic axis lies partially in the crazed area.

Conclusions

There is a wide range of commercially acceptable bright glazes of this type maturing from cone 12 to cone 16 having a heat range of from four to five cones.

The best glazes lie along a high gloss axis which is practically a straight line represented by the approximate formula $Al_2O_3 = 0.3 + {}^1/_{12}\ SiO_2$.

The range in silica content for a given temperature is wide and becomes greater as the maturing temperature is raised, the possible variations being between 3 to 13 equivalents of SiO_2. The range in alumina content for a given temperature is very much narrower than the range in silica content.

There is a deformation eutectic axis for this series which lies below the high gloss axis and partially in the crazing area.

The best bright glazes for each heat treatment are found at the center of the area of mature good glazes on the chart.

Mat glazes of this type in which the alumina is high enough to give an alumina: silica ratio of 1:4 for 3 to 6 equivalents of silica and tapering down to 1:6 for 10 equivalents silica are aluminous mats and not mats of immaturity since increasing heat treatment will not change them to bright glazes.

Glazes of this type containing 55% or more flint show segregation and will not lie down to smooth surfaces from cone 12 to cone 16.

The proper way to correct crazing in this type of glaze is by increasing the alumina through the addition of clay. Higher firing causes the crazing area to recede but not enough to make higher firing a safe way to correct crazing, except in the glazes containing 4 or less equivalents of silica. There seems to be evidence that this type of glaze will craze when overfired sufficiently, which might be worthy of further investigation.

Addition of flint to this type of glaze will not stop crazing, but if carried far enough may throw the composition of the glaze into the crazed area. This is in agreement with Stull who found that Seger's rule did not hold for this type of glaze.

The writer wishes to acknowledge and to express his appreciation of the advice and suggestions of Mr. A. V. Bleininger in this work, and to thank Mr. Robert Sherwood for making the bisque.

Bureau of Standards
Washington, D. C.

A TERRA COTTA INDUSTRY FOR OHIO[1]

By Arthur S. Watts

ABSTRACT

Two terra cotta industries using Ohio clays existed in Ohio prior to 1860. Today no terra cotta industries exist within the State, although Ohio has the clay, fuel and skilled labor. One Ohio clay, the Tionesta or No. 3 B, is especially adapted for terra cotta. It crosses the state through Vinton, Hocking, Perry, Muskingum, Coshocton, Tuscrawas and Stark Counties.

The occurrences and chemical composition as determined by the Ohio Geol. Survey are given by the author.

This clay burns with a shrinkage of about 6 per cent and a porosity of about 8 per cent from cone 2 to cone 5 with practically no color variation. It will carry its own weight of non-plastic without serious loss of mechanical strength.

Successful combinations and working directions for body, engobe, glaze and vitreous slip are given.

Ohio is recognized as the leading state in the Union as regards production of clay products and the question "Why is there no terra cotta industry in Ohio?" has frequently been asked. This question is hard to answer. Through the courtesy of the Ohio Geological Survey I have the information that Ohio was one of the pioneers in terra cotta manufacture. The Federal Census of 1860 shows that at Cincinnati there were two terra cotta plants in 1859. Mr. N. U. Walker added in 1878 to his general plant at East Liverpool a department for the manufacture of terra cotta. This was soon recognized as a producer of some of the finest terra cotta manufacture in the country, and in 1878 to 1900 it produced about four tons of terra cotta per day. Why these terra cotta plants did not continue and develop with the modern terra cotta industry of the United States is not recorded. It is certain that the materials for the industry were not lacking as the terra cotta industries elsewhere are shipping their raw materials and fuel much farther

[1] Received April 7, 1921.

than would be necessary in either of these cases. The most plausible explanation is that the manufacture of terra cotta was crowded out by the great demand at that time for other ceramic wares in the manufacture of which less skilled labor was required and for which the manufacturing losses were less.

But why should Ohio not have a terra cotta industry to-day? The demand for structural material is as great as any other state in the Union can boast and yet Ohio cities must go to Indianapolis or Chicago on the west or to New York or Philadelphia on the east for the terra cotta which they use. We have Cleveland, Youngstown, Akron, Toledo, Columbus, Dayton, and Cincinnati, all cities of over 125,000 population, with about a dozen other cities of 35,000 to 75,000 population annually buying large amounts of terra cotta. And Ohio has all the essentials for a heavy clay industry. These are clay, fuel and skilled labor. Let us consider first the clay. Here Ohio excels, I believe, as we have several clay formations that are ideally suited for terra cotta. I shall mention only one which in any other state would quickly cause development of a terra cotta industry.

The Ohio Geological Survey furnishes the following information: The Tionesta or No. 3 B clay belongs to the upper part of the Pottsville formation and occurs below the Tionesta or No. 3 B coal. This is overlaid by shale or sandstone above which occurs the Brookville clay and coal which are the separating members between the Pottsville and Allegheny formations. In places the Tionesta and Brookville clays are separated only by a thin coal bed or by this and a few feet of plastic red burning shale.

This clay deposit crosses the state from Lawrence County on the south to Mahoning County on the east where it passes out into Pennsylvania. It varies somewhat in thickness and composition from place to place but in much of the area is of excellent quality. It is of best quality in Vinton, Hocking, Perry, Muskingum, Coshocton, Tuscarawas and Stark Counties. Northeast of Stark County it is so covered with glacial drift that its general character is not well known.

Occurrences

Section at McArthur, Vinton County.
McArthur Brick Company.

	Ft.	In.
Coal—*Brookville*	4	0
Clay—Dark siliceous	4	0
Shale—gray	28	0
Shale and covered	4	0
Coal—Tionesta	1	8
Clay—Tionesta, light, siliceous	4	0
Shaley sandstone (3′–7′)		

Section at Logan, Hocking County.
Logan Clay Products Co.

	Ft.	In.
Sandstone—yellow	20	0
Shale—gray	18	0
Shale—blue, fossiliferous	4	8
Limestone—very fossiliferous	0	11
Coal—Tionesta	0	6
Clay—Tionesta, dark	0	6
Clay—Tionesta, light, flinty in places	2	10
Clay—Tionesta, light, siliceous	0	6
Clay—Tionesta, light, plastic	8	8
Clay—Tionesta, light, siliceous	1	6
Sandstone, light clay bonded	20	0

Analysis of Logan Deposit

H_2O 105°	2.67
Ignition loss	9.05
SiO_2	52.29
Al_2O_3	28.38
Fe_2O_3	2.68
CaO	0.23
MgO	0.25
TiO_2	1.80
K_2O	2.07
Na_2O	0.35
MnO	trace
P_2O_5	0.06
S	0.27
Total C	0.38
Inorg. C	0.03

Section at Roseville, Muskingum County, fusion temperature cone 27–28. Chas. Drake Mine.

	Ft.	In.
Sandstone	5	0
Clay—shaley, plastic	0	11
Clay—Tionesta—dark carbonaceous	0	2
Clay—Tionesta—light plastic	5	10
Shaley sandstone		

Analysis of Roseville Deposit

H_2O 105°C.	2.83
Ignition loss	6.30
SiO_2	60.00
Al_2O_3	22.37
Fe_2O_3	2.68
CaO	0.41
MgO	0.13
TiO_2	1.65
K_2O	2.59
Na_2O	0.31
MnO	0.01
P_2O_5	0.01
S	0.02
Total C	0.30
Inorg. C	0.03

Section at Ellis, Muskingum County. Fusion temperature cone 26+. Roseville Pottery Co.

	Ft.	In.
Limestone—Putnam Hill	5	7
Shale	0	6
Coal—Brookville	0	3
Clay—Brookville	2	5
Shale and shaley sandstone	3	10
Shale—soft	5	0
Clay—Tionesta—dark	0	2
Clay—Tionesta—light plastic	2	8
Clay—Tionesta—light siliceous	2	8
Shale		

Analysis of Ellis Deposit

H_2O 105°C.	2.37
Ignition loss	7.76
SiO_2	57.13
Al_2O_3	25.13
Fe_2O_3	2.11
CaO	0.28

MgO	0.11
TiO_2	1.68
K_2O	2.36
Na_2O	0.19
MnO	0.01
P_2O_5	0.03
S	trace
Total C.	0.21
Inorg. C.	0.01

Section at East Sparta, Stark County.
Federal Clay Products Co.

	Ft.	In.
Limestone—Putnam Hill	2	0
Coal—Brookville (weathered)	1	2
Clay—Brookville (upper part dark)	6	0
Shale	12	0
Coal—Tionesta (shaley)	0	2
Clay—Tionesta, light, plastic	3	0
Clay—Tionesta, quite siliceous	5	6
Shale		

Analysis of East Sparta Deposit

H_2O 105°C.	1.70
Ignition loss	6.37
SiO_2	61.93
Al_2O_3	21.86
Fe_2O_3	2.56
CaO	0.50
MgO	0.72
TiO_2	1.60
K_2O	2.33
Na_2O	0.17
MnO	trace
P_2O_5	0.05
S	0.01
Total C.	0.26
Inorg. C.	0.02

At Logan, this clay is used for sewer pipe and stoneware, burned at about cone 6. At Roseville, it is used extensively for stoneware and also for saggers for yellow and white ware. Fired at cone 5–6. At Zanesville, art pottery, stoneware, buff floor tile, art tile, and saggers for all these are manufactured. Fired at cone 2 to cone 8. Chemical stoneware is also made by an Akron concern.

The Wassal Fire-Clay Co., Columbus, O., used this clay from Logan for making terra cotta from 1876 to about 1888. It was considered by Dr. Orton to be of first rank as regards finish.

As regards fuel, the state of Ohio is very fortunately situated, having coal which can be obtained at very favorable prices. Oil is also as easily obtained here as anywhere in the East. Gas as a fuel is no longer obtainable for kiln firing in any pottery center.

As regards labor, Ohio should have no difficulty as she has had clayworking industries for so many years that she possesses a large class of clayworkers who are natives and would certainly furnish the men necessary to do the manual labor in a terra cotta plant. The problems of manufacture are of course different from those of other ceramic industries but not sufficiently so to minimize the value of a training in general clayworking for the future terra cotta workman. The ability to draw workmen from general clayworking plants located in the same district would be an enormous advantage in establishing a terra cotta industry.

Now to show what can be done with this single Ohio clay. We have obtained the different clays used in the manufacture of terra cotta in every portion of the United States and have found that for the bonding strength, color, low porosity and heat range the Tionesta clay gives us the equal of any mixture of clays used elsewhere. This clay burns at cone 3 to a strong body of about 8 per cent absorption and can be burned to cone 6 or 7 without material increase in shrinkage which averages about 6 per cent. The color does not change appreciably between cone 2 and cone 5 and the clay has sufficient plasticity to carry its own weight of non-plastics without serious loss of mechanical strength. In fact I have used a mixture of 40 per cent of this clay and 60 per cent of grog graded between 20 mesh and 80 mesh and produced a body of excellent strength and sufficiently smooth to take a glaze. For best results I find, however, that a body consisting of 60 per cent Tionesta clay and 40 per cent grog, finer than 20 mesh, is preferable and I have used this for general terra cotta colors and for engobe and vitreous slip studies for several years.

For this body I use an engobe consisting of:

Tennessee ball clay	15
English china clay	35
Feldspar	13
Whiting	2
Flint	35
	100
K_2CO_3	1

This engobe is applied by spraying at a weight of 22 ounces per pint.

Over this engobe the following clear glaze is placed:

$$\left.\begin{array}{ll} 0.1 & K_2O \\ .1 & Na_2O \\ .4 & CaO \\ .3 & ZnO \\ .05 & BaO \\ .05 & MgO \end{array}\right\} \quad \begin{array}{r} 0.3\ Al_2O_3\text{—}2.4\ SiO_2 \\ 0.1\ B_2O_3 \end{array}$$

Apply at 22½ ounces per pint.

This body, engobe and glaze all mature at cone 2 and do not overfire at cone 5.

A vitreous slip that worked excellently has the following composition:

Cornwall stone	40
English ball clay	18
English china clay	20
Boric acid	2
Flint	15
$CaCo_3$	2
$BaCO_3$	2
MgO	1
	100%

A STUDY OF THE OPERATION OF A DRESSLER TUNNEL KILN[1]

By Charles J. Hudson

ABSTRACT

Before installing a Dressler tunnel kiln, Norton Company made a study of an existing kiln. At Steubenville, Ohio, the kiln was found to be working well; repairs were small, economy in fuel, labor and firing time had resulted. The heat distribution was found to be variable but subject to control. The amount of rejected ware was very small and in no case could it be charged definitely to the kiln.

This kiln was investigated by the writer for a period of five weeks for the purpose of determining its desirability as an addition to the kiln equipment of Norton Company. Permission has been obtained from both the American Dressler Tunnel Kiln, Inc. and Mr. Geo. W. Cochran, Secretary and Treasurer of the Ohio Valley Clay Company to publish the results of the observations for the benefit of those who are interested in tunnel kilns.

The success of the investigation was made possible by Mr. Cochran's kindness to the writer; he was quite willing to facilitate the tests and it was a pleasure to discuss the results with him. Thanks are due him at the outset for allowing this work to be done.

General Description

There is a considerable amount of literature available relating to the principle upon which the Dressler tunnel kiln is based, notably in volumes 17 and 18, Transactions of the American Ceramic Society. A brief description of the kiln, however, may not come amiss here.

The kiln is of the muffle type. The fires are in refractory muffles on either side of a track extending the length of the

[1] Received July 21, 1921. Read before the New England Section of the American Ceramic Society, May 26, 1921.

kiln. The firing zone is about midway of the length. The ware, which is placed upon cars, is sent gradually through the kiln by means of a pushing device located at the head end; it is gradually heated by the products of combustion drawn through ducts along the kiln walls between which it passes, fully fired while passing the firing zone, cooled gradually as it approaches the exit and finally when taken from the kiln is ready to be removed from the cars.

Figure 1 is a schematic drawing of the cross section of the kiln. Combustion takes place in the double walled, trapezoidal shaped chambers on either side; these chambers are located throughout the forward end of the kiln and extend somewhat beyond the

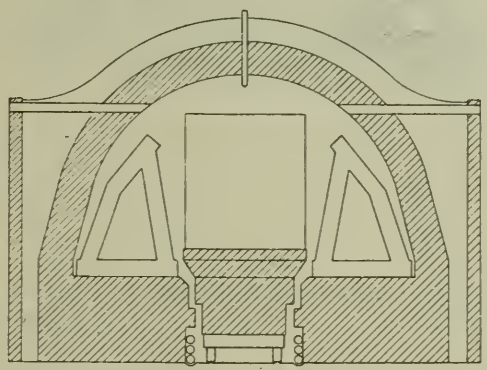


FIG. 1.—Schematic drawing of Dressler kiln through firing zone.

middle. Combustion takes place in the chambers at about the center of the kiln; the products of combustion are brought toward the forward end by means of an exhaust fan connected to the long lines of chambers on either side. Thus the chambers can be thought of as long horizontal double-walled chimneys between which the ware passes on its journey through the kiln.

The transfer of heat from the chambers to the ware probably takes place in two ways: (1) by radiation; (2) by convection currents through the channels between the inner and outer walls of the chambers. The chambers are constructed so as to allow the atmosphere of the kiln to circulate around them and yet the gases of combustion can not escape into the kiln.

After passing the soaking zone of the kiln the ware passes between pipes on either side of the kiln chamber which extend from the exit end of the kiln nearly up to the burners. Air from the kiln shed is taken into these pipes near the exit end of the kiln, brought nearly up to the burners and there exhausted outside the kiln. As the air passes through the pipes

Fig. 2.—General appearance of outside of kiln; picture taken from near exit end. Note the intake ends of the cooling pipes for one side.

it becomes heated by abstracting heat from the ware close to it. The ware, as it leaves the soaking zone, passes between these pipes relatively hot at first but much cooler toward the exit, The cooling air is always in the pipes and so does not come in contact with the ware, hence the cooling also is done by radiation and convection.

The iron framework and wheels of the cars are kept cool by the circulation of water in pipes close to these parts.

The pusher is built on the principle of a horizontal screw jack, and is motor driven. After reaching the end of its stroke either forward or back it stops automatically.

Dimensions

This kiln is about 300 feet long by about 14 feet wide at the widest part, outside dimensions. The tie rods binding the buckstays together are about 11 feet above the floor. The cross section of the kiln is such that ware can be set 48″ above the car floor and 44″ wide. The car floor is about 30″ above the track.

At the entering end of the kiln a space of about 12 feet by 6 is required for the pushing machine which moves the cars through the kiln.

Movement of Cars

Outside of the kiln, and running parallel to it, is a trace where the cars are unloaded and set. After being set they are run onto a transfer truck at the entrance of the kiln. This transfer is run into the kiln with the car on it and locked so that the car can be pushed onto the track within the kiln. Outside the kiln and in line with the track running through the kiln is the pusher, which pushes the entering car into the kiln and at the same time pushes the line of cars within the kiln ahead of it.

During the period of operation one car was put into the kiln every four hours, or six cars a day. Since the kiln held 47 cars, it required just under eight days for the cars to go completely through. The average rate of travel was 1½ feet per hour. At the same time that a car was being pushed into the kiln another car was being pushed onto a transfer at the exit end. Before another car can be put into the kiln, this car on the exit transfer must be taken out and put on the outside track.

At either end of the kiln the openings for the cars were closed by rolling metal doors; these were kept closed except when cars were either locked in or taken out. The cars were set entirely outside the kiln previous to locking in; the ware was removed from the cars not far from the exit end of the kiln at a place convenient to the warerooms.

Cars

The cars were built up on a cast iron frame each supported by four roller bearing wheels. The superstructure was made of hollow fire-clay blocks filled with Sil-O-Cel powder. The floors of the cars were made of heavy clay slabs which were directly supported by fire-clay girders. These are well shown in figures 3 and 4. The dimensions of the car floor, and thus the setting area, are 44″ by 72″. The floor is supplied with a number of holes which allow convection currents to pass through the ware and thence through the channels around the muffles.

The iron frame of the car was two inches longer than the clay superstructure. As the cars were pushed through the kiln, each pushed all the cars ahead of it by means of the iron frames. Each car was provided with a tongue on one end and groove at the other in the fire-clay piece near the bottom thus presenting a baffle for the heat, tending to keep the iron frame cooler by preventing direct radiation. The cars weigh about two tons and their setting capacity is in the neighborhood of three tons. They were numbered and always kept in numerical order, thus making it easy to locate a car in the kiln.

Outside the kiln the cars could be readily pushed by hand. When taken from the exit transfer they were pushed a short

FIG. 3.—General appearance of an empty car.

way along the outside track to the drawing locality; after drawing, the car was pushed toward the setting location which was near the forward end of the kiln. After setting the setting gang pushed the car toward the head end to await its turn into the kiln. The location of the setting position was at such a distance from the head end of the kiln that enough space was allowed for the number of set cars to last over Sunday. Similarly, at the other end, the unloading space was far enough away from the exit so as to allow space for all the cars which came out during Saturday and Sunday.

Pyrometer Equipment

A good pyrometer equipment is quite essential on any tunnel kiln. The correct temperature curve having been determined

for the ware, it is only necessary to hold the temperature constant throughout the soaking zone in order to insure proper firing. Cones cannot be used to control the burning in the way they are in a periodic kiln; they should be used frequently however, to check the firing conditions. In a periodic kiln the temperature is raised or held steady until the desired cone deformation is reached. In the tunnel it is impossible to hurry or slow up one car without doing the same to the entire train. Therefore after the kiln temperatures have been regulated so that the desired cone deformations are reached, then these temperatures should be held constant. A good pyrometer is invaluable for this purpose.

Other instruments can probably be used to good advantage on a Dressler kiln; draft gauges and combustion meters would undoubtedly prove of value. At Steubenville the kiln was provided with a pyrometer equipment and a draft gauge for obtaining the draft at different points in the combustion chambers.

Heat Distribution

At intervals throughout the length of the kiln thermocouples projecting down into the crown about 2″ were supplied for measuring the temperatures at these points; couples were also inserted into the combustion chambers, at nearly the hottest place. The temperatures at two couples in very nearly the hottest place in the crown and at one couple in the combustion chamber on either side were recorded; at all other points, seventeen in all, the temperature was indicated.

Figure 5 gives the heat curve of the kiln throughout its length. The general shape of the curve (except at station 11) is correct although the actual temperatures recorded in the soaking zone of the kiln may be in error. The temperatures were measured in most cases with a platinum-rhodium thermocouple and a Leeds and Northrup potentiometer. At a few of the stations however the kiln couples could not be readily moved in their protection tubes so the best attainable temperature as given by the couple at that point was used. All readings were corrected for cold junction temperature. Stations 16 and 17 were located in the conbustion chambers, one in either side. It will be noted

that these temperatures ran about 100° higher than the highest kiln temperature indicating good heat conducting properties of the silicon carbide chambers. Not much reliance could be placed in the reading at No. 11 station; the couple was apparently not giving truthful readings yet it could not be removed without further injury, a step which the writer could not readily undertake.

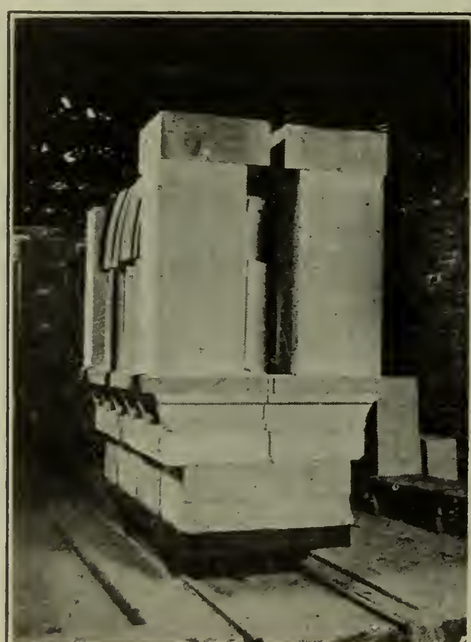


FIG. 4.—A car just out of the kiln.

The curve in figure 5 is a distance—temperature curve and should not be confused with a time-temperature curve usually given for kilns; it would become a time-temperature curve if one hour were substituted for each one and one-half feet. If the rate of travel were hastened, *i. e.*, made faster than 1½ feet per hour, the effect would be to compress this distance-temperature curve horizontally in order to obtain the time-temperature curve. This curve and the time-temperature curve coincide when the rate of travel becomes one foot per hour. During the time of observation the rate of travel was 1½ feet per hour; at intervals since then it is understood that this kiln has been run successfully as fast as two feet per hour.

TABLE OF TEMPERATURES AT THE STATIONS INDICATED ON FIGURE 2

Station	Cold junction temperatures, °C	Corrected temperatures, °C
1	25	214
2	33	385
3	30	535
4	38	765
5	40	1030
6	40	1108
7	58	1145
8	110	1199
9	136	1197
10	75	1165
11	46	585?
12	35	601
13	30	458
14	28	389
15	27	211
16	80	1299
17	70	1292

The temperature at either end of the kiln was fairly high; at the entering end it was close to 150°C, and the ware came out at 160°C. The temperature at the top of the kiln was much higher than at the floor of the car at the two ends. Although these temperatures may seem high they were not too

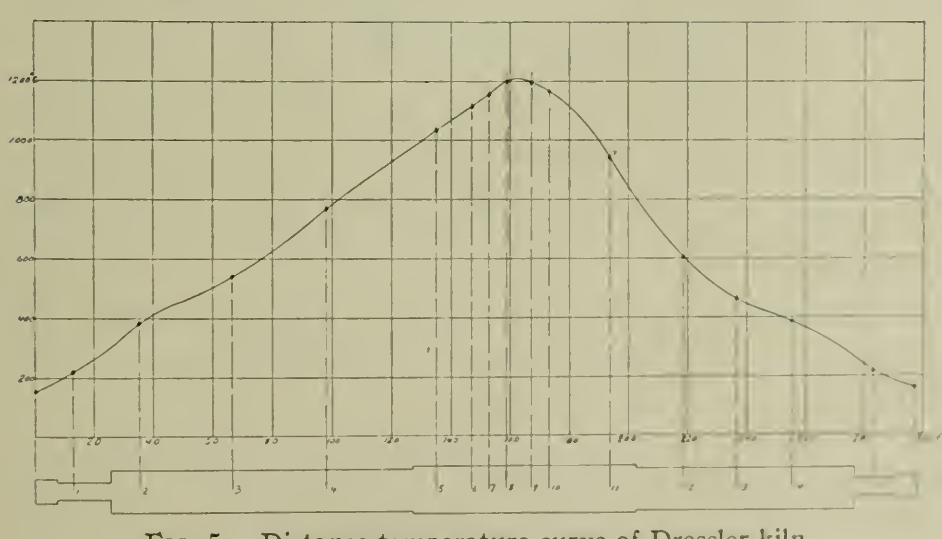


FIG. 5.—Distance-temperature curve of Dressler kiln.

high for the ware put through this kiln. A kiln constructed for ware which would not stand these entering and leaving temperatures could readily be designed.

The longitudinal temperature curve is a mechanical achievement; given the required curve through which a certain ware must pass for its proper maturity and cooling, a Dressler kiln can be constructed which will fulfill the required time-temperature requirements. The real test of a kiln of this type comes when at the same time a demand is made that the heat distribution through the cross section shall be within certain limits. Considerable time was spent in studying the cross sectional heat distribution. This was done by means of distributing pyrometric cones and Veritas discs at many points over the setting space.

The cross sectional heat distribution was found at times to be very good—less than one-third of a cone—and at other times faulty—as much as two cones difference. This may look discouraging but in reality is quite the opposite, for if the distribution had always been poor no matter how it was aided by changing setting methods then there would have been reason for lack of enthusiasm for the kiln. Since the distribution was at times very good, the problem was to find out why it was good and to try to so operate the kiln that it would always be good. The real solution turned out to be openness of setting; cars set fairly open gave good heat distribution; when set close or tight the distribution was not so good. This does not necessarily mean that cars can not be set tight with good heat distribution but it probably does mean that a good distribution can not be obtained where tightly set cars are locked into the kiln with openly set ones; a uniform setting should be adopted for best results.

The data for the heat distribution results follow: Cone pats were made up of cones 9–10–11–12. Veritas discs were usually placed with the cones.

Figure 6 shows the result of one test made over the cross section of a car; the top cone pats show cone 11 fairly well down whereas at the bottom cone 11 is only about half over. At both

the top and bottom it appears that the center was not so hot as the outsides. The figures on the discs represent the shrinkage in percentages; these vary from 8.05% to 8.45%.

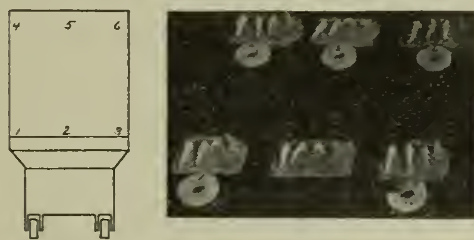


FIG. 6.—Left—Diagram showing the positions where the cones were set. Right — Cones 9, 10, 11, 12 after passing through the kiln.

Figure 7 shows the result of a second test where again the differences in cone deformation amounted to less than half a cone. There is a tendency here indicating that the car was hotter on the outside than at the center at both top and bottom.

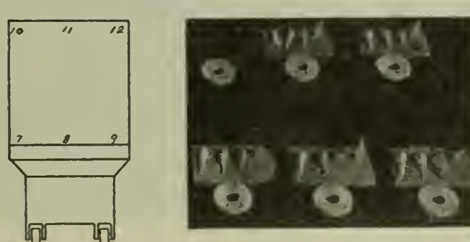
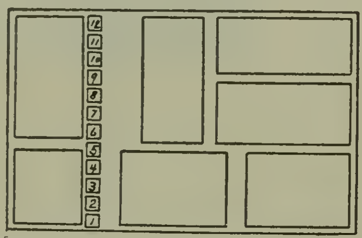


FIG. 7.—Left—Diagram showing the positions where cones were set. Right—Cones 9, 10, 11, 12 after passing through the kiln.

From the above it will be seen that the greatest difference in temperature throughout a car is as likely to be from center to outside as from top to bottom. Figure 8 illustrates a test made to see if a more open setting might improve the heat distribution from center to outside. A row of cones and discs were set across a car between flux blocks set rather openly; the floor plan is attached and shows a space of eleven inches wide extending across the car. An inspection of the cones shows only infinitesimal differences. These results are checked by the discs which show practically no differences in percentage shrinkage.

Several other tests were made which showed that the cones must be placed in relative positions in order to compare them; for example, cones exposed toward both sides and top showed a greater deformation than cones which were protected by ware from the top. This is an indication that there were convection currents moving through the muffle walls and the ware, as claimed by the American Dressler Tunnel Kiln, Inc.



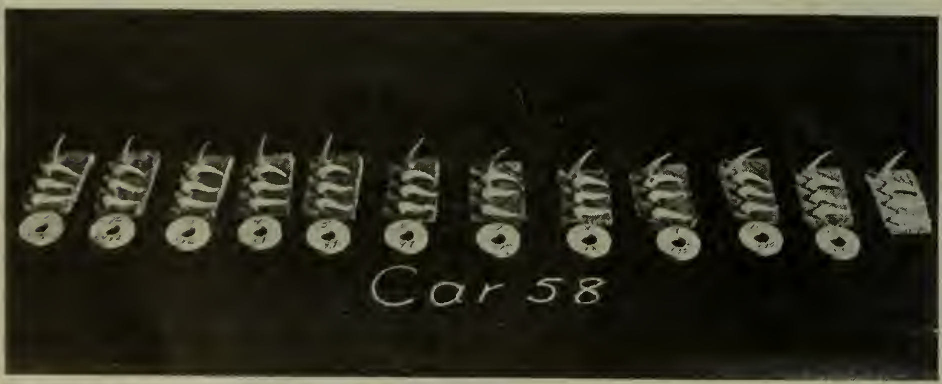


FIG. 8.—Above—Floor plan of car showing where cones were set between the ware. Below—Cones 9, 10, 11, 12 after passing through the kiln.

Defective Ware

The ware manufactured by the Ohio Valley Clay Company is glass house refractories. A large portion of the ware put through the kiln during the time of observation was rectangular shaped blocks weighing from three to seven hundred pounds; occasionally there would be set a piece weighing over a ton and often times on the same car with pieces weighing only a few pounds.

The amount of defective ware coming from the kiln was surprisingly small, and it is possible that the cause of rejection originated in the dryroom. A few pieces which were thought to

have minute cracks were marked before locking into the kiln; these always came out cracked. For this particular ware the kiln is admirably suited. No damaged ware came through during the five weeks observation, which could be definitely charged to the kiln.

Kiln Repairs

The kiln had been running about eight months at the time of observation; it was remarkably free from cracks, in fact, there were no obvious ones, but in looking for them there were found two fine hair-like cracks which were of no consequence.

During this time the cars had been without repairs. While the writer was at Steubenville three cars were repaired; a portion of the top slab was replaced on each. These were said to be the first repairs to the cars.

There is a considerable amount of mechanical equipment connected with the kiln, two fans, a water pump and the pusher, all motor driven. None of these had given the slightest trouble, yet they had seen twenty-four hour per day service since the kiln was started. Although this is a remarkable achievement for the mechanical equipment it would seem that considerable chance is being taken in operating a kiln of this sort without duplicate parts. The stoppage of the main draft fan means that the fuel supply must be immediately turned off to avoid filling the kiln shed with smoke. The cooling air fan or the water pump could not properly be down for more than an hour.

During the eight months period which the kiln had run up to the time of observation there had been one shut down of a purely accidental nature. A workman dropped a plank on the rheostat governing the motor operating the water pump; this stopped the pump and, since it ran very silently, nobody noticed that it was stopped for some time. Upon discovery of the stoppage the pump was started; in the meantime the water pipes had become quite hot and when the cold water was pumped in, the quick contraction of the pipes broke some of them allowing water to escape into the kiln chamber. In order to repair the trouble the kiln had to be partially cooled. A loss of about ten days resulted.

Fuel

The fuel used at this kiln was natural gas, which is an ideal fuel for the Dressler kiln. The amount used averaged about 73,000 cubic feet every twenty-four hours; occasionally the consumption reached 82,000 and on one day it was as low as 65,000 cubic feet. The gas pressure was held constant by regulators on the main line and also on each line running to either side of the kiln.

The reason for the wide fluctuation in gas consumption is not quite clear. Two possible reasons present themselves, changes in the B. T. U. value of the gas and improper combustion. No means of determining the B. T. U. value were available. Neither was there a means of directly determining the composition of the exhaust gases at hand, but certain fluctuations in the kiln temperatures indicated that the best combustion possible may not always have been obtained.

The temperature of the exhaust gases was about 240°C, showing that most of the heat of combustion had been given up to the ware before being exhausted out of doors.

This kiln was built with the proper facilities for burning producer gas. A gas producer was installed in close proximity to the kiln but had never been used up to the time of observation. It has recently been learned that this kiln has been run with producer gas with excellent results. The kiln is readily adaptable to either natural, city or producer gas and fuel oil.

Kiln Capacity

It is somewhat difficult to make a just comparison of kiln capacities where the wares burned are of varying types. The Dressler kiln is admirably adapted to the burning of glass house refractories where the ware possesses sufficient strength to require no saggering and its shape is well adapted to economical setting on the car tops.

At the Ohio Valley Clay Company the Dressler kiln was doing the work of nineteen periodic kilns of various sizes. Their operating time had been cut from twenty-one days to about eight days and their output had increased fifty per cent. Their gas consumption had been cut by an enormous amount and a

saving in labor of about 50% was claimed. All these claims looked entirely possible after watching the manner in which their ware was handled and comparing these methods with a mental picture of their former methods.

To express the capacity of a Dressler kiln in terms of periodic kilns, one must make an intelligent guess unless considerably more is known about the best time-temperature curve of a particular ware than can be gained by the operation of a periodic kiln. For example, we attempt to operate a periodic kiln so that all ware comes out good, the temperature rise is slow enough so as not to overheat the outside ware in the water smoking period and as a result the center ware is raised over-cautiously for we can not do otherwise; likewise in cooling we must cool for the outside ware and let the center ware take a much lower rate. In other words we are dealing with a large unit which is always at non-uniform temperatures and which must be fired over-cautiously so as to be on the safe side.

If the exact time-temperature curve by which a ware must be fired is known then, given the relative setting areas of the two kilns, it is entirely possible to express the capacity of a Dressler in terms of periodic kilns. In general, however, the temperature and safe minimum time to which a ware can be successfully fired is not known and because of this the Dressler kiln is able to cut down the time of firing in periodic kilns. Since the kiln gives practically uniform cone deformation throughout the cross section it is evident that the car rate can be started safe and then speeded up to the limit which the ware will stand. Just what ultimate rate the ware will stand must be more or less of an intelligent guess unless this rate has been determined in some other manner than in a commercial kiln, as for example in a laboratory furnace.

There is another reason which makes the time-temperature guess for ware fired in a periodic kiln still more problematical, this is the condition of the kiln atmosphere. Whether the atmosphere is oxidizing or reducing is not always known for a periodic kiln, nor is the part played by the atmosphere always known. In the Dressler kiln the atmosphere can be controlled and its effect upon the ware studied.

Taking these points into consideration the best guess we could make as to the capacity of the Dressler kiln was somewhere between five and ten periodic kilns. The periodic kilns compared are what are known as fifteen foot, down-draft, circular kilns; the setting space is about thirteen and one-half feet in diameter between bag walls and about ten feet high.

Economy

It must be readily admitted that a periodic kiln is extremely wasteful of fuel. A Dressler kiln, and probably tunnel kilns of other makes, will undoubtedly save fuel. An estimate of fifty-per cent savings is conservative.

The savings in labor by the use of a Dressler tunnel kiln, or other car tunnel kilns is somewhat problematical. At Steubenville on natural gas the care of the kiln was under one man who also had charge of the setting and drawing. At night the watchman put in a car every four hours, but was frequently at places remote from the kiln during the interim. As far as manual labor is concerned one man on a shift can take care of the kiln lock in the cars and take them out. If producer gas is used an additional man on the producer would probably be necessary.

The saving in setting and drawing labor resulting from a tunnel kiln must depend somewhat on the type of ware and the methods in use with periodic kilns. Where large heavy pieces are fired mechanical means can be used to good advantage on the Dressler cars for both setting and drawing. The saving resulting where the ware is small and uniform in size and comes to the kiln in saggers will be less than where it is large, irregular in shape and must be packed in quartz at the kiln. The fact that all ware is set in the open at one place and drawn in the open at another should result in a saving of labor over that required for a periodic kiln because the working conditions are much more pleasant.

Additional Dressler Kilns

During the time of investigation at Steubenville advantage was taken of the opportunity to visit other plants in that vicinity where five additional Dressler kilns were seen. Although no

study was made of these kilns, conversations with the operators of them proved that they were giving entire satisfaction both in reduction in cost and in quality of ware. All of these kilns were burning natural gas although they were equipped for burning producer gas and in some cases had operated on it.

Possible Difficulties

The stopping of a Dressler kiln is of a somewhat serious nature; it causes contraction and its attendant cracking which is objectionable. The low cost of maintenance of this kiln is probably dependent upon its continuous operation. A few of the possible difficulties which may be encountered are listed here.

The combustion chambers may burn out. These should be made of the proper material to withstand the temperatures used and the action of the fuel.

Suitable fire-brick should be chosen for the crown; the weight on the crown is small but the continuous heat allows the crown to become hot throughout its thickness.

Care must be exercised in setting so that no ware will fall off a car inside the kiln. Some ware lends itself very well to stable setting; this is particularly true at the Steubenville kiln. But there are other wares which can not be set so stably, as flux blocks, and here great care must be used.

The stoppage of fans or the pump is serious but this may be eliminated by a duplicate equipment.

Advantages

The Dressler tunnel kiln can usually give a saving in firing time; this is because its cross-sectional heat distribution is practically uniform.

A saving in fuel can undoubtedly be accomplished.

Waste heat from the kiln can readily be used for heating or drying purposes.

The expense account for repairs should be small. At all plants visited where repairs had been made an accident had been the direct cause.

A muffle kiln gives better combustion control than an open-fired kiln. Where ware is usually saggered the need is elimi-

nated by the muffles in the Dressler kiln. The need for saggers for protecting the ware from discoloration is eliminated in the Dressler kiln where the fires are enclosed in muffles. The muffles may seem like needless expense where muffling of the ware is not necessary, but it is believed that better combustion control and more uniform and constant temperatures can be maintained by their use than without.

The atmospheric conditions within a kiln are often times important; some wares require an oxidizing and others a reducing atmosphere. In the Dressler kiln the atmosphere is always oxidizing unless it is made reducing by the admittance of a particular gas.

There should be a saving in breakage of kiln furniture in the tunnel over that resulting from a periodic kiln. The setting height is from one-half to one-third that of the periodic kiln, therefore there is a correspondingly lesser weight on the furniture. The uniform heating and cooling with the elimination of occasional flashing ought to prolong kiln furniture life.

Summary

The Dressler kiln was found to be giving very good satisfaction at the Ohio Valley Clay Company as well as at a number of other plants.

The cross-sectional heat distribution seems to be subject to control and differences greater than half a cone can probably be eliminated.

The control of the kiln seemed very simple, at least with natural gas.

Savings in fuel can undoubtedly be made by the use of this kiln. Savings in labor, rejected ware, kiln furniture, and kiln repairs can probably be made over those required for a periodic kiln.

A saving in firing time over that required in a periodic kiln ought to be accomplished; its amount can only be estimated. At Steubenville, the firing time had been cut to one-third the periodic kiln time.

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HIGH TEMPERATURE TESTING FURNACE[1]

By W. M. Hepburn

ABSTRACT

A surface combustion furnace lined with alundum and fed by seven burners supplied from a mixture box in which an explosive mix. of gas and air is made by a special inspirator melts down cone 36 in one hour using 156 cu. ft. of city gas. The max. temp., 3400°F, attained is within 200°F, of the theoretical max. Advantages claimed are: Simplicity, low fuel consumption, ease of observation and measuring temperatures and ability to produce either neutral, reducing or oxidizing atmosphere.

Introduction

The testing of refractories requiring temperatures over 3000°F has generally been regarded as beyond the gas furnace domain. The numerous possible applications for small inexpensive gas fired furnaces capable of attaining temperatures up to 3400° F should make developments along this line of particular interest.

A study of the conditions to be considered in producing these temperatures in a gas furnace is necessarily closely connected with the maximum temperature obtainable for any particular gas fuel, that is, the so-called flame temperature. Flame temperature occupies a rather indefinite position and is only obtained by theoretical calculations. These calculations show that combustion of average city gas with cold air is capable of producing a temperature of approximately 3600°F. The question of greatest importance, however, is how nearly can this temperature actually be realized at some useful point?

Gas fired crucible furnaces which have at various times been constructed for this type of work may be listed in 3 classes. One of each of these classes was constructed and comparative tests run to determine the maximum possible temperature attainable inside a container. The three classes together with the average maximum temperature obtained with each class are as follows:

[1] Received May 16, 1921.

1. The gas mixture is supplied tangentially, combustion taking place against the furnace lining. Max. *t.*, 3100°F.

2. The flame envelops the crucible upon which it is concentrated by various baffle arrangements. Max. *t.*, 3200°F.

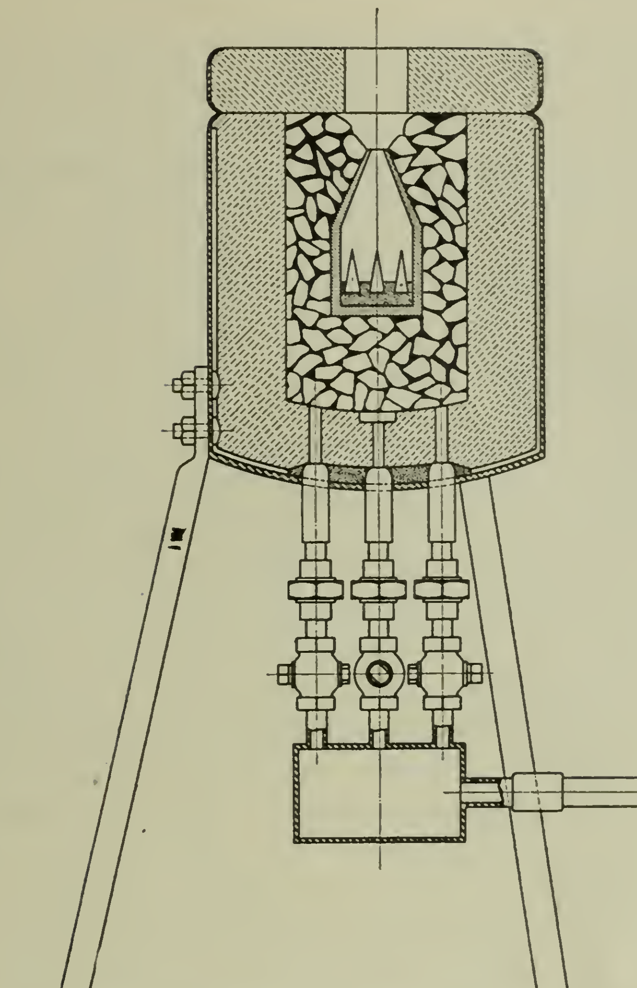
3. Surface combustion type. Max. *t.*, 3400°F.

As this article is intended to deal more with practical results than with theories pertaining thereto, no attempt will be made to account for the difference in these temperature limits other than to say that the basic idea of the original surface combustion as invented by Prof. Bone and Dr. Lucke was to burn an explosive mixture of gas and air inside the pores of some refractory material. This method produces a maximum amount of radiant heat, and the resulting light wave energy greatly accelerates the chemical reaction of the gas mixture. The above tests show that it is possible by the use of these principles to attain a temperature within 200° of the theoretical maximum.

Description of the Furnace

The construction of the furnace in which these results were obtained is shown in the accompanying illustration. The furnace consists of a heavy cylindrical metal casing lined with a special alundum mixture the fusion point of which is approximately 3500°F. The cover consists of the same refractory material. Gas and air mixed in an inspirator of a special design built inside of a tee are fed to the mixture box. From the mixture box the explosive mixture is delivered by 7 pipes to corresponding burners, each pipe being provided with a cock. The receptacle in which the test pieces are placed consists of an alumina crucible two inches in diameter capable of accommodating 5 one-inch Seger cones or test pieces. This crucible is placed in and supported by the refractory material. This refractory is of the same material as that used for the lining but in lump form.

A small size lump checks the flow of the gas, while a coarser one gives less resistance to the flow. The temperature limits of the furnace are very sensitive to the selection of the proper size refractory. The selection now used when properly filled in and with a mixture pressure of twelve inches on 7 burners melts down cone 36 within an hour, consuming 156 cu. ft. of city gas.



A funnel-shaped cover with an opening at the top for observation is placed over the crucible containing the test cones. This cover is so designed as to enable all parts inside of the crucible to be observed at any time during the operation thereby enabling the temperature readings to be taken with optical pyrometers.

Procedure for Determining Fusion Points of Test Pieces

In making standard fusion tests a very gradual rate of heating is required. Therefore the furnace is usually started with only one central burner open at some low mixture pressure. As the furnace begins to heat up two opposite outside burners are opened up, then two more and so on until all 7 burners are opened. Further increase of temperature can be attained by

increasing the mixture pressure. Due to the use of 7 burners and the possibility of wide range in mixture pressures any amount of gas between 6.5 and 160 cu. ft. can be burned per hour. Increasing the gas rate beyond this point has no effect on the temperature

If desired, high temperatures can be obtained within half an hour, starting with a cold furnace. These sudden rises in temperature, however, are detrimental to the lining.

The samples of clay to be tested are given the same shape and size as small Seger cones. The cones are fastened on the bottom of the crucible with moistened white alundum cement or powdered alumina which has been burned at high temperature. Thus for instance a cone of clay and 4 Seger cones are fixed in the crucible. The temperature of the furnace is increased, observations being made from time to time. At the point where the test piece sags over, the gas is shut off and the furnace allowed to cool sufficiently to permit the removal of the crucible. The condition of the accompanying Seger cones will indicate the fusion point of the test pieces with a degree of accuracy dependent upon the difference between the fusion points of the Seger cones selected. Sufficient air under 3 lbs. pressure must be available. If an individual blower is used in connection with the furnace it is an advantage to bypass the excess air of the blower and by regulating the bypass, control the air pressure at the furnace. To enable observation from short distances the flame issuing from the top opening is blown to one side by an air blast thereby permitting the observer to approach to within 10 inches of the top of the furnace.

Some of the important advantages of this type of furnace are namely: Simplicity, low fuel consumption, ease of observation and measuring temperatures and ability to produce either a neutral, reducing or oxidizing atmosphere. In this way the test cone can be subjected to conditions identical with those under which the material is to be used. Carbon or graphite resistance furnaces usually used for this type of work have a strongly reducing action on clay, which action influences the melting point by reducing the iron oxide and producing other complex reactions.

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REFRACTORIES UNDER LOAD CONDITIONS[1]

By H. J. Knollman

ABSTRACT

Life factors.—The life of fire clay slabs, rings and saggers is influenced by a number of factors, both mechanical and chemical. The chief factors controlling the life of the slabs are (1) proper selections of clays and grog, (2) medium absorption or porosity, (3) strength in the unburned state, (4) proper and thorough blending and preparation of the mix, (5) proper pressing so as to insure freedom from flaws, (6) proper drying, (7) proper setting in the kilns and especially (8) initial burn. These factors are briefly discussed.

Setting.—The manner of setting grinding wheels, using large slabs is described. This manner of setting causes transverse bending stress to be set up in the slab and shear stresses to develop. This shearing force, in connection with the large size and the high temperature (cones 11 to 12), make severe conditions for the slab to withstand.

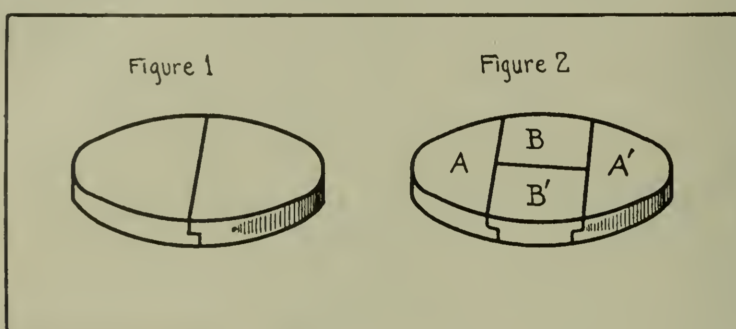
Shape and size.—The rate of heating and the size and shape of the slabs are additional factors. Round slabs, up to about 20" in diameter have a decidedly longer life when made in two half sections as compared with the solid shape. Larger slabs have longest life when split up into four sections, while if solid they will fail in one burn. Warping of the slabs, as well as cracking, causes failure. In general, if the width of area of the load is held constant, and length of span of the slab is increased, deformation and cracking is slightly increased. If the span is held constant, and the width or load area is increased warpage is greatly increased, especially as the number of burns under load increases. Cracking also increases in direct proportion to increase in width. These features are more pronounced the longer the span.

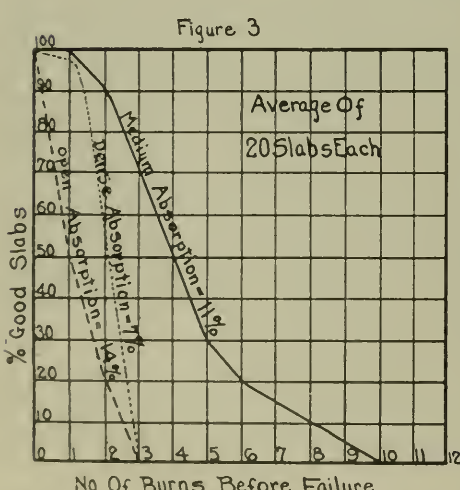
Ultimate failure at high temperatures.—When not due to structural defects, failure is brought about by a gradual decrease in mechanical strength from burn to burn, so that fire-clay slabs under transverse load at such temperatures have decided limitations.

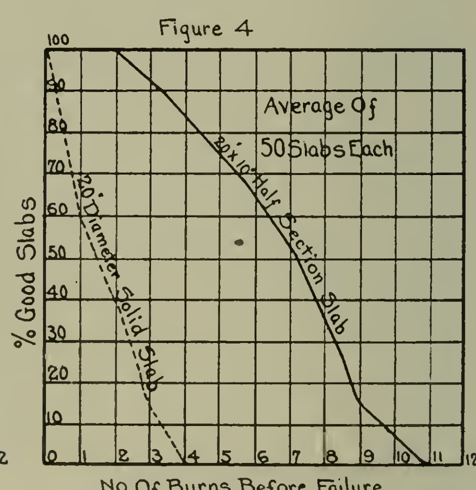
The ability of fire-clay slabs, rings and saggers to carry load at elevated temperatures is one of importance and concern to many clay working industries, but probably in no industry is it of such vital concern as in the abrasive or grinding wheel industry. This is due not only to the fact that the refractories are called upon to carry heavy loads under rigid conditions, but also because of the large sizes of slabs involved as well as the comparatively high temperatures to which they are subjected.

[1] Received April 16, 1921.

Since grinding wheels varying from a fraction of an inch to 30 inches in diameter are manufactured, slabs to support them in the kiln must necessarily vary similarly in diameter. It is, therefore, customary to use saggers or solid one-piece round slabs up to about 20 inches in diameter for the smaller wheels. The larger sizes are made more economically and are more readily handled if subdivided into two or more sections. Interme-







diate sizes are, therefore, customarily made in half sections with a ship-lap joint as in figure 1, while the larger sizes are conveniently made in quarter sections as in figure 2.

One of the prime requisites is that of strength in the raw unburned state. With individual slabs weighing from a few pounds up to 150 pounds, the strength in the raw state must be sufficiently great to prevent undue breakage or cracking before the slabs are burned.

The selection of the individual clays and their proper proportions are of no greater importance than the control of the manufacture of the slabs themselves. In fact, experience has demonstrated that the selection of the fire-clays, as long as they are good clays within a safe field of usefulness, is not so important as close attention to the various details in the manufacture. While the usual laboratory tests for shrinkage, warpage, transverse strength, absorption, porosity, et cetera, form valuable guides, the selection of the clays is, however, based primarily upon compromise between these different properties, the undesirable as well as the desirable ones.

All other factors being constant, a slab which is tight and dense, no matter how strong it may be, will, under load, have a short life, owing to its inability to withstand the strains incident to the repeated heating and cooling. A slab which is too open, on the other hand, will be weak and fragile and will not be able to stand either the weight of the load or the strain to which it is subjected. A fairly large field of intermediate density gives slabs which have sufficient strength and hardness to sustain heavy loads and are also porous and open enough to stand volume changes and warpage strains under repeated heatings and coolings.

Figure 3 shows the relation between number of burns before failure and per cent of "goods" for three types of slabs similar in all respects, except that the absorptions were varied by changing the relative proportions of tight and open burning clays going into the mix. Although the degree of vitrification of these clays enters in as a factor, it is slight as compared with variation in degree of openness.

Both the very open slabs and the very dense slabs failed to the extent of 100 per cent in 3 burns at cone 11. The medium porous slabs (10 to 11 per cent absorption), deteriorated much more gradually under the same conditions, the last slab failing in the 10th burn. In fact, a certain amount of strength in the burned state is sacrificed in order that the slabs may be sufficiently open.

The shrinkage of the various clays used is of importance, not only in governing the dimensions of the slabs, but also as a

factor in determining their mechanical strength. The quantity of high shrinkage clays in a mix may be carried to a point where the clay portion will shrink away from the grog to such an extent as to form numerous fine cracks between the grog and clay portion throughout the slab. Outward manifestations of this condition are frequently observed in saggers which have numerous fine hair cracks on their surfaces. The greater the proportion of highly shrinking clays used, the more pronounced does this condition become, and when carried to excess, the slab becomes distinctly lower in mechanical strength. This, therefore, very largely offsets the advantages to be derived from the elimination of low shrinking, high sandy clays, with their attendant volume changes.

The size of grog used in the mix also affects the load-carrying capacity. For slabs which are to carry heavy loads, especially those subject to severe transverse bending, coarse grog is necessary to help keep the body sufficiently open, as well as to prevent excessive shrinkage and cracking. Grog, about 4 mesh to 20 mesh in size, is used to the amount of 50% and all fines are eliminated. Even a small amount of fines in the regular slab mix has a noticeable detrimental effect on the life of the slab. But where the refractories are merely under compression, as in the case of the rings used to support the slabs in a stand, fine grog gives additional strength and is there used to advantage.

Having made a proper selection of clays, usually about 50 per cent plastic tight burning clays, and 50 per cent less plastic open burning ones, it becomes important to secure an intimate mixture. Unquestionably the dry or wet pan gives the best results. Where the ordinary soaking pit method is used, sufficient time must be given for the slaking down of the clays in water and to insure a certain degree of softening in the case of some clays. Thorough pugging of the clay mix is then very necessary. As long as lumps or particles, even though small, of the individual clays used can be distinguished in the mix, the grinding and preparations of the mix are not complete or satisfactory.

The density of the prepared clay mix ready for pressing is also a point to be considered. This density is largely controlled

by the amount of water used in tempering, mixing and pugging. The denser and more compact the structure of the mixture, provided it is not too dry, the harder will be the burned refractory made from it. If too dry, the individual lumps used to make the slab will not press and knit together properly. A mix which is too wet, on the other hand, will not give as dense a structure and as compact a slab as one of proper working consistency.

Pressing of the slabs, especially the larger sizes, is an important operation. Care, and some skill and strength on the part of the presser are necessary to produce a slab free from internal flaws. These flaws are mainly of two types, (1) the more or less long narrow crack within the interior of the slab, sometimes quite wide and not visible from the outside; and (2) holes of varying size or round smooth depressions within the interior of the slab sometimes having small radial cracks leading from them. These flaws are caused by the failure of two or more lumps of clay to become perfectly welded and knitted together when pressed in the mold. The individual pieces of clay remain to an extent. Best practice requires that a lump of clay large enough to approximately fill the mold be used, while exerting a harder pressure also helps.

The dried green slabs, preparatory to the initial burn, must be set in the kiln as tightly and closely together as possible. If they are set even slightly loose and irregularly, they will upon contraction during the burn warp out of shape, which generally renders them unsuitable for further use. Overburning will tend to produce the same undesirable result. Where they are set so as to reinforce each other, contraction will be uniform over their entire area and warping will be prevented. The necessity of having all slabs and saggers perfectly dry before they go to the kiln for the initial burn is obvious, as is also the necessity for a slow water smoking period.

The heat treatment to which the slabs are subjected is of paramount importance, probably more so than any other single operation. Every clay mix has a definite distinct temperature at which maximum strength is developed which in turn largely governs its load carrying ability and maximum service. Slabs requiring a heat in the original burn a few cones higher than

they are to be subjected to later have a longer life than those requiring the same heat for proper maturity. The former are less subject to warping and deformation under load.

Table 1 gives the results of a study made on slabs, free from cracks, of the same dimensions and composition, which were given the heat treatments indicated. The 14 slabs were burned to cone 12 half down to down. The 20 slabs were burned from cone 13 bent to about half down, while the 34 slabs were

TABLE 1

No. of slabs	Initial burn cone	Per cent with no cracks	Per cent slightly cracked	Per cent badly cracked	Per cent broken
14	12	0	21	29	50
20	13—	15	40	35	19
34	13+	38	44	15	3
53	14	68	24	4	4

burned at cone 13 three quarters down to 14 well bent. The 53 slabs were burned to cone 14 down, the temperature required for proper vitrification and best maturity for this particular composition. These temperatures, while not exact, do represent distinct differences in the final heats obtained and the slabs show definite differences in hardness, appearance, etc.

They were then used with loads consisting of regular grinding wheels. Those under the "No cracks" column came out of the kiln with no signs of a crack whatever. "Slightly cracked" slabs were those having a relatively short fine crack, very short large crack or a long very fine crack after drawing from the kiln. These types of cracks in general are not serious enough to cause the slab to break in the succeeding burn. "Badly cracked" slabs are those with a long large crack which generally causes breakage of the slab in question in the following burn.

These results showed conclusively that the initial burning of the slabs is very important and has considerable influence upon their life. Those burned to cone 12 were soft and underburned and can be safely counted upon to last only one burn. Those burned to cone 13 not more than half way down are quite better, although nearly 50 per cent are badly cracked or broken. Those burned to cone 13+ showed still greater improvement, while those burned to cone 14 down showed up very well, only 8 per cent being badly cracked or broken.

Some of the same slabs after close observation and recording of their condition were again placed under regular load, and upon being drawn were re-examined in order to trace the progress in cracking. These results are given in Table II.

Table II

	Cone 13— slabs, per cent	Cone 13+ slabs, per cent	Cone 14 slabs, per cent
Crack same as before........	0	12	54
Increased width of crack.....	55	40	15
Increased length of crack....	31	10	12
New cracks developed.......	14	38	19
Total number of cracks......	42	40	41

Here again is shown in a striking manner the difference between a well burned slab and one slightly less well burned. Those burned at cone 12 were so poor that it was useless to test them in a second burn. Those at cone 13—, while not appreciably underburned, according to appearance, showed that every slab tested increased in either the width or length of crack. Those at cone 13+ showed that but one out of eight cracks did not increase in width or length and generally the increased length and width of crack was particularly marked. The slabs burned at cone 14 down, on the other hand, showed over 50 per cent remaining in the original condition. Although the cone 13— slabs do not show up newly developed cracks as strongly as the cone 13+ and cone 14 slabs, this is in reality due to the fact that the cracks previously present increased to such an extent as to make it unnecessary for new cracks to develop.

Slabs slightly overfired have a longer life than underfired ones, but not as long as the best. This is largely due to the fact that such slabs are generally slightly warped. The initial burn is, therefore, not only very important but is entirely independent of the subsequent heats to which they are subjected. The practice, so often prevalent, of putting green slabs in odd places in the kiln containing regular ware, where they generally receive the greatest or else the least heat is poor practice. Likewise, the tendency to burn a kiln full of green slabs in a careless manner is just as detrimental to best results.

In setting the kilns with wheels, it is necessary that the bottom slabs be supported upon a firm foundation, consisting of

brick piers at frequent intervals. A thin layer of sand is then spread uniformly over the surface of these bottom slabs. Fire-clay rings are then set around and near the periphery of the slabs, and the grinding wheel is set directly in the center. In the majority of cases, coarse sand is placed between the wheel and the ring, and sometimes the wheel is firmly imbedded in the coarse sand. Another set of slabs is then placed upon the rings, clay wads separating them. A layer of sand, an abrasive wheel in the center and rings on the outside are placed as before, the rings being placed directly in line with rings underneath. This process is repeated for the entire height of the stand.

It will be seen from the manner of setting that the slabs are in compression only at the points where the upper and lower rings are superimposed upon each other, together with the section of the slab between them. The rings together with this small cross section in compression, therefore, carry the weight of all the layers above, whether this weight is that of a dozen or more layers near the bottom or only one set at the top. Since fire clay refractories are able to withstand high compressive forces, as compared to transverse stresses, the refractories seldom, if ever, fail from this source. Each slab or set of slabs, on the other hand, carries the weight of the wheel and its quota of sand, and the greater part of this weight is concentrated toward the center. Since the abrasive wheel occupies the center portion of the stand, no supports of any kind can be placed under the slabs to support them, or to relieve the transverse bending effect. The load applied in the center of the stand, therefore, acts as a shearing force, and a shear is developed when the slab fails. They are all subjected to the same conditions with the exception of the bottom slabs, which are well supported over practically their entire area, and those used on the top of the stand, which carry no load. It is a matter of experience that cracked and warped slabs occur anywhere in the stand, towards the top in about the same ratio as in the center or bottom of the stand, with the exceptions noted.

Since a temperature of cone 11 to 12 is required for the burning of grinding wheels, the slabs are subjected to severe heat treatment in addition to rigid load conditions. A gradual

softening then takes place, as evidenced by warping of slabs of long span, and the mechanical strength is lowered. That increases in temperature have a marked influence on the life of the slab is beyond question. The scrap pile is always larger if the kiln has been burned to cone 12 as compared with cone 11. A quick burn as compared with a slower one to the same temperature also rapidly increases breakage, which is likewise the case with rapid cooling. Warping, cracking and decrease in strength are all increased at a very rapid rate if the burn is conducted under reducing instead of oxidizing conditions.

The smaller slabs are made round and solid, but a point is soon reached where it is more economical to split them into two sections, not only because of increased ease in manufacture and handling, but also because of the increased life. Figure 4, for example, illustrates the relative life of a solid one piece slab of about 20″ in diameter compared with that of half-section slabs made as shown in figure 1. Each half section, being in effect a semi-circular slab, then has a greatest length of 20 inches and a maximum width of 10 inches. These slabs were subjected to the same conditions throughout.

It will be seen that the solid slabs cracked excessively under load conditions and that the breakage was very high from the start, all failing in 4 burns. The half-section slabs on the other hand, did not fail at all for a few burns then a gradual failure set in and after several burns the rate of failure increased rapidly. The last half-section slabs to fail did not do so until the 11th burn. The outstanding difficulty with the solid slab is that it generally develops a long crack somewhere towards the center, which frequently divides it into two sections. In doing so, however, it develops additional radial cracks, which soon cause it to break into 3 or more pieces, when it is worthless for further use. When half sections are used the slab not only may be regarded as already being cracked in two pieces, but there is also a decidedly less pronounced tendency for radial cracks to develop, since there is some elasticity in a two-section slab while it is being subjected to expansion and contraction strains, which is not possible in a solid slab.

As the diameter of the stand increases, the dimensions of the

two-section slabs increase accordingly. The maximum length and the maximum width of the semi-circular slabs increase in the definite ratio of 2 to 1, but the effect of these increases upon the tendency to fail is not in a like ratio. A definite slight increase in width plays a greater part in tendency to failure under load than the corresponding double increase in length. This is partly due to the fact that larger, heavier wheels are placed upon the larger slabs, thus increasing the load, but it is due to a far greater degree to the larger area subjected to the load. In general, the wider the semi-circular slab becomes, the greater the tendency to failure from cracking. If carried far enough, these semi-circular slabs become so large that they in turn will crack excessively in one burn and all will fail in a few additional burns.

Because of this and the greater ease of handling, et cetera, the larger slabs are subdivided into four sections as shown in figure 2. A slab, 30″ in diameter, for example, if made solid will, regardless of the thickness, not last more than the first burn under load. Indeed, it will crack excessively and in most cases fail, merely under its own weight. If made in two sections, each section has a short life before failure. If made in four sections, however, each section will have a comparatively long life.

Failure, besides taking place through the development of cracks, is also brought about through warping of the refractories. The warping tendency is greatly increased by transverse bending loads, and is always present. In the smaller two section slabs, it is not very pronounced, not only because they are frequently reversed, if they are but slightly warped in one direction, but also because the span is not large. In the large four-section slabs, however, this factor becomes very prominent. The side pieces AA′ of figure 2 are especially subject to deformation, because of their long span, since their length is great compared to the width. The superimposed weight on the slab is also unequally distributed, since it is centered in the middle over a comparatively small area. The center pieces BB′ are not subject to this deformation in a like degree, since their span is much shorter and the weight of the abrasive wheel upon them is distributed over the greater portion of their area. They would be subject to just as severe a defoımation if they were made

as one long center piece across the entire span, but when made as two center pieces BB′, they may be regarded as a long center piece already cracked in the middle, so that the warping and cracking tendencies are very materially reduced.

Just as the rate of failure of the half-section slab is increased as the width of the slab increases, so also does this rate increase as the width of the four-section slab increases. This holds true of both the side and center pieces, although the manner of failure is somewhat different, in that warpage or deformation is pronounced in the side pieces, but not in the center pieces.

If the width of the side pieces is held the same and their length or span is increased, deformation and consequent failure is increased in proportion to the increased span. If the span is held constant, and the width, and incidentally the area of the load is increased, warpage of the slabs is very greatly increased. This deformation in general, however, does not take place in the first load burn, but is a gradual accumulation of successive burns, the degree of warpage increasing at a much faster rate in the wider slabs than in the narrower ones. The narrow side piece slabs do not warp to any great extent, even after a number of burns, but will fail from cracking in much the same way as do the smaller half sections. The wide side piece slabs, on the other hand, warp at first very gradually, almost imperceptibly, and then more rapidly. Their load conditions are most severe because in addition to their span, they also are called upon to hold up in place the center pieces with their superimposed loads.

The center pieces have a longer life, since their load is distributed over the greater portion of their area, so that the condition approaches more nearly that of compression, especially in the smaller sizes. In fact the breakage of the smaller sizes is slight, so that they have an almost indefinite life. As the dimensions increase, however, failure increases proportionally. As long as the span between the side pieces does not become great, they will generally fail across or parallel to the width. When the span becomes large, however, the greater proportion crack lengthwise, *i.e.*, perpendicular to the span. If the center pieces become very large, they will fail at a comparatively fast rate, much the same as wide half-section slabs.

The thickness of the slabs plays a rather unimportant part. If they are too thin, they will be too weak to carry heavy loads and to stand any rough handling. Too thick a slab, however, not only requires excess clay, but cracking is increased.

That volume changes play an important part in the deterioration of all slabs is evidenced by the fact that those that have failed after several burns generally exhibit numerous fine cracks, where the clay matrix has shrunk away from the grog. Where the load conditions are such that warping and cracking do not readily take place, the slabs do not give much evidence of this, although such volume changes must have taken place to a lesser extent. That failure in general is due to a combination of causes is seen in the fact that there is no great uniformity in the life of slabs, made of the same mix, in the same way, and subjected to the same size and manner of load. Some will outlive their mates by several burns.

In general, then, in tracing the progress of deterioration of slabs under load at high temperatures, the first slabs to fail are those structurally defective, that is, those having flaws, laminations, et cetera. Then there is a gradual decrease in mechanical strength, due to physical and chemical changes taking place in successive burns, until the point of failure is reached, which in turn is largely influenced by the relation of the load to the strength and position of the refractory. But after all, fire-clay refractories have decided limitations under the conditions given, so that the need of "superior refractories" having constancy of volume, high mechanical strength, ability to carry load at high temperatures, and to withstand sudden temperature changes and which are economical at the same time, is very apparent.

Abrasive Company
Philadelphia, Pa.

CERAMIC ABSTRACTS

Author Index[1] to Abstracts for September

[1] The abbreviation (*C. A.*) at the end of an abstract, etc., indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. **Recent progress of the ceramic industry.** KIYOHARU KONDŌ *J. Chem. Ind.* (Japan), **23**, 764–75(1920).—Progress of this industry in Japan is represented by incorporation of 107 new manufg. houses in 1919. Past and present activities are discussed for manufg. of bricks, pipes, tiles, fireproof utensils, china ware and other porcelain, glass, for plate and bottle, silicate glass, elec. globes, and cements. S. T. (*C. A.*)

2. **Industrial tuberculosis and the control of the factory dust problem.** C. E. A. WINSLOW AND LEONARD GREENBURG. *J. Ind. Hyg.*, **2**, 333–43, 878–95(1921).—A critical study with bibliography. The first installment is devoted essentially to the relation between industrial dusts and respiratory disease. The second installment contains sections on: method of studying dust content of air, variations in dust content of air from normal and industrial environments, control of dust hazard (by substitution of wet for dry processes, by conduct of dust-producing operations in enclosed chambers, by operation of hoods and local exhaust ventilation, by wearing of respirators and helmets), importance of definite analytical standards in control of industrial dust hazards. JOSEPH S. HEPBURN (*C. A.*)

3. **Investigations of the chemical literature.** FRANK E. BARROWS. *Chem. Met. Eng.*, **24**, 423–8, 477–9, 517–21(1921).—A valuable general survey of methods and facilities. Library facilities, general reference books, the periodical literature, indexes, patents, etc., are discussed. The importance of proper training and guidance in making investigations of the chemical literature is emphasized. E. J. C. (*C. A.*)

4. **The future of ceramic education in America.** EDWARD ORTON, JR. *The New Jersey Ceramist*, **1**, 8(1921).—The author reviews briefly the diff. systems of ceramic education which are in effect throughout the world.

He then discusses the American system of education in ceramics, its history and the results. He states that the pottery industry has been the most reluctant to accept the young graduate and gives the following reasons: 1—The unionized closed shop; 2—The influence of the conservatism of the English potters and their successors; 3—A mistaken notion of self sufficiency and superiority on the part of the potter.

The author is of the opinion that thus far the trade school training in this country has failed to play an important part in our educational system because of peculiar psychological conditions which prevail and consequently, if American potters wish to develop trade schools, they must adopt entirely different measures from those which have been tried. Attempts to combine or to associate closely the trade school and the technical school will fail.

C. W. PARMELEE

PATENTS

5. **Method for handling bricks.** JAMES B. LADD. U. S. 1,373,513, April 5, 1921. The method of handling bricks which consists in forming stacked units with the top course arranged to form parallel channels, the chan-

nel forming bricks suitably spaced to form a support for a similar superimposed unit and at the same time to povide recesses for receiving lifting elements beneath the superimposed unit resting upon the channel forming layer, and for permitting the withdrawal of the elements therefrom, and translating the stacked unit by inserting the lifting elements into the channels beneath the unit and moving same.

6. **Clay Press.** RALPH F. MEYER. U. S. 1,373,903, April 5, 1921. In a clay press, the combination with a die member, of a hollow mold adapted to contain plastic material and coöperating with the die member for forming a longitudinal opening in the plastic material, means for moving the mold toward and away from the die member, a plunger movable toward and away from the interior of the mold, and automatically actuated means for reciprocating the plunger.

7. **Process and apparatus for drying crucibles.** LOUIS VERGNIAUD, Paris, France. U. S. 1,373,688, April 5, 1921. A process for drying crucibles consisting in placing the crucibles in inverted position on a heated surface, subjecting the interior of the crucibles directly to a continuous circulation of hot air, and the exterior to the heat given off by the heated surface.

C. M. SAEGER, JR.

Apparatus and Appliances

8. **Indicators for carbon dioxide and oxygen in air and flue gas.** L. H. MILLIGAN, D. O. CRITES AND W. S. WILSON. Bur. of Mines, *Tech. Paper* **238**, 23 pp.(1920).—Construction and operation are described of portable instruments designed in the research lab. of the Pittsburgh expr. station. CO_2 is absorbed by NaOH; O is absorbed by alk. pyrogallate. For details see the original. JEROME ALEXANDER (*C. A.*)

Refractories and Furnaces

9. **New German refractory product.** ANON. *Chem. Met. Eng.*, **24**, 1070.—A new method of making firebrick more refractory has been perfected in Germany, consisting of a coating comprising a mixture of 75 per cent carborundum and 25 per cent sodium silicate. The mixture is applied to the bricks when they are thoroughly dried, and the coating sets and thoroughly dries in twenty-four hours, being slowly heated and burned in. This coating averages about one-fiftieth of an inch in thickness, and the adherent glassy veneer of carborundum gives remarkable resistance to any mechanical injury. It is claimed to withstand very high and rapidly varying temps. and affords complete protection against the chemical action of flames. This coating has been used successfully as a lining for gas retorts as well as for the outside surface. A paste of equal parts of carborundum and clay is used for repairs when cracks occur. H. F. S.

10. **The outlook for the magnesite industry.** ANON. *J. Elec. West Ind.*, **46**, 245–6(1921), 2 illus.—Extensive deposits of cryst. magnesite occur in Stevens Co., about 60 miles from Spokane, Wash. American interests

control approx. 80% of the magnesite deposits of the world. The daily consumption of plastic magnesite in the U. S. is about 100 tons; it is used in a cement which has enduring qualities and sets speedily. C. G. F. (*C. A.*)

11. **Tentative method for ultimate chemical analysis of chrome ores and chrome brick.** ANON. *Proc. Am. Soc. Testing Materials,* **20,** I, 647–51 (1920). —*1. General method.* Dry the fine powder at 110° for not less than 1 hr. Cool in a desiccator. Fuse 0.5 g. of the sample with approx. 10 g. of fused $KHSO_4$ in a Pt crucible. The most refractory ores should be thoroughly fused in $1^1/_2$–2 hrs. Allow the crucible to cool in the air and dissolve the fusion in 200 cc. hot HCl (1:1), boiling until the soln. acquires a clear green color. Evap. to dryness on a water bath and bake at exactly 120° until free from HCl fumes. Moisten with hot HCl (1:1), evap., and bake as before. Dissolve in 200 cc. hot dil. HCl and filter SiO_2. Ignite and weigh the SiO_2, detg. the SiO_2 by treatment with HF and H_2SO_4. Any appreciable residue should be fused with $KHSO_4$ and added to the filtrate. Dil. the filtrate to 500 cc. and ppt. Fe, Al, Cr and Ti with NH_4OH in very slight excess. Filter, dissolve in HCl and reppt. Again filter the combined hydroxides and dissolve in HNO_3. Evap. in a casserole adding crystals of $KClO_3$ from time to time until the Cr is completely oxidized. Dil. with hot H_2O and again ppt. with NH_4OH, filtering as before. Repeat the oxidation 2 or 3 times until the filtrate shows no further traces of Cr. Combine the filtrates and evap. to 500 cc. Add H_2SO_3 until the soln. changes to a brilliant green color and heat to boiling. Add a very slight excess of NH_4OH, filter, wash, ignite, and weigh as Cr_2O_3. The hydroxides of Fe, Al and Ti are ignited and weighed. Fuse the combined oxides with a small amt. of $KHSO_4$, dissolve the fusion in dil. H_2SO_4, reduce with H_2S and titrate with $KMnO_4$. Det. the Ti colorimetrically and calc. the Al by difference. To the combined filtrates from the hydroxide pptn. add Br, allow to stand a few min. and then add sufficient NH_4OH to ppt. the Mn. Boil, filter, ignite, and weigh as Mn_3O_4. From the filtrate ppt. the Ca with NH_4OH and $(NH_4)C_2O_4$ and det. in the usual way either by ignition to the oxide or by titrating with $KMnO_4$. Det. the Mg in the filtrate from the Ca ppt. in the usual way as $Mg_2P_2O_7$, and use the J. Lawrence Smith method for the detn. of alkalies. *2. Rapid routine method.* Fuse 0.5 g. of the fine dry sample with 8–10 g. of Na_2O_2 in a Ni or porcelain crucible. Leach out with cold H_2O, boil 15 min., cool, and add 100 cc. H_2SO_4 (1:1). Cool, and titrate the Cr with ferrous soln. and $KMnO_4$. To detn. Si and Fe, fuse 0.5 g. of the sample in a Ni crucible, leach out with cold H_2O, acidify with HCl and evap. to dryness. Take up with 200 cc. of H_2O and add 10 cc. HCl. Filter SiO_2 and if necessary repeat the evapn. and filtration. Make the filtrate alk. with NaOH and add 5 cc. Br. Digest $^1/_2$ hr. on a steam bath. Filter $Fe(OH)_3$ on asbestos, dissolve and reppt. Filter again, dissolve in hot HCl, reduce with $SnCl_2$ and titrate with $KMnO_4$ in the usual way.

S. G. SIMPSON (*C. A.*)

12. **The importance of air supply in combustion of coal.** HENRY KREISINGER. *New Jersey Ceramist,* 1, 39 (1921).—A general discussion of the

processes of combustion and their control in the operation of hand fired furnaces. About 14 pounds of air must be supplied to each pound of bituminous coal burned. This includes from 25% to 50% excess over the theoretical quantity but it is necessary to obtain nearly complete combustion in commercial furnaces. In hand fired furnaces if the fuel bed is 5 to 6 in. thick, only 6 or 7 pounds of air to a pound of coal can be supplied through the grate; the other 7 pounds must be supplied over the fuel bed. If larger quantities of air are forced through the grate the rate of combustion is increased but the same proportionate amount of fuel is burned. Thus 70 lbs. of air passed through each sq. ft. of grate will burn 10 lbs. of coal. Thick fuel beds almost invariably cause clinker. A fuel bed 4 to 5 in. thick kept level will give a reducing atmosphere as well as one 12 in. thick. Soot, the main constituent forming visible smoke is formed in, or near, the fuel bed and not when the hydrocarbons strike the cooling surface of the boiler. If oxygen is supplied in sufficient quantity right at the surface of the fuel bed, soot is not formed. Because of the intermittent feeding of fuel in hand firing it is difficult to provide always a sufficient quantity of oxygen over the fuel bed to·burn the volatile matter completely. Probably the best practice is to have an air supply which is just sufficient to meet the requirements as they exist immediately after firing. Graphs are used to show the relation between percentage excess of air and carbon dioxide content for the combustion of Pocahontas, Pittsburgh and Illinois coal. Graphs are used also to show variations in CO_2 content in the furnace gases at intervals of a few minutes during the firing of Pittsburgh, Pocahontas, Anthracite and No. Dakota lignite. Heat losses in operation of a boiler plant are: 35% in the stack gases, 4% by radiation, 4% due to unburned coal falling into the ash pit. 57% of the heat is utilized in making steam. The loss in the stack gases can be largely avoided by reducing the excess air. If furnaces are operated so that the CO_2 content of the flue gases is increased from 6 to 12%, there will be a reduction of 10% in the stack losses and 6 tons of coal will do the same work as 7. The principal causes of large excess of air are holes in the fire, leaky settings and needlessly kept open doors. Firing every 3 minutes is not too often. Frequent poking of the fire causes excessive chimney losses. C. W. P.

PATENTS

13. Refractory brick. CHARLES W. BERRY. U. S. 1,373,854, April 5, 1921. A process of manufacturing refractory material consisting in first mixing the desired proportions of magnesite and bauxite in a raw condition, the mixing water the same, then burning the resultant product at a temperature sufficient to drive off moisture and gas; next, regrinding the calcined product and mixing with water; finally forming same into a suitable shape, and burning such to produce a hard refractory article.

14. Refractory material. EDWARD D. FROHMAN. U. S. 1,372,016, March 22, 1921. A refractory material consisting of a mixture of finely divided dry fire clay, siliceous material and a vegetable compound capable when mingled with water of forming a binder.

15. **Arch-brick.** WILLIAM SCHUTTLER. U. S. 1,372,320, March 22, 1921. An end arch brick for boiler fire box arch constructions provided on one end with a surface adapted to take against a side sheet and on the other end with a substantially vertically extending convex surface adapted to swinging of the brick on a substantially vertical axis.

16. **Tunnel-kiln.** GLENN E. NORMAN. U. S. 1,372,773, March 29, 1921. A tunnel-kiln comprizing a longitudinal structure, the walls and dome of which are provided with longitudinal air passages the full length thereof adapted to be heated by the heat affecting the walls of the structure, and an exhaust air directing compartment at one end of the structure into which all of the longitudinal air passages enter. C. M. SAEGER, JR.

Chemistry, Physics and Geology

17. **Methods for determining the amount of colloidal material in soils.** Preliminary paper. CHARLES J. MOORE, WM. H. FRY AND HOWARD E. MIDDLETON. Bur. Soils, Dept. Agr., Wash. *J. Ind. Eng. Chem.*, **13**, 527–30 (1921).—*Prep. of mat.* After 24 hrs. in settling tanks the supernatant liq. was passed through a Sharples centrifuge and the colloidal mat. in the issuing liq. was sep. by passing through Pasteur-Chamberlain filters and further purified by dialysis and washing.

Properties of ultra-clay. The "ultra-clay" thus obtained was typically colloidal in behavior showing marked Brownian movement, flocculation by electrolytes, and high plasticity and stickiness in the moist condition. Up to a content of 10%, briquettes made with the ultra clay are stronger than those made with Port. cement.

Absorption of ammonia. After calcining at the temps. indicated, the following results were obtained.

Cecil Ultra-Clay

Temperature °C	110	265	374	559	754	1130
Cc. NH_3 absorbed per cc. colloid	110.3	100.8	80.0	74.1	57.5	2.2

Susquehanna Clay Soil

Temperature °C	110	190	265	374	522	673	844	1130
Cc. NH_3 absorbed per cc. soil	27.7	25.3	24.8	19.7	14.9	13.6	7.4	1.4

Calculation of colloidal content. In the light of the above results, the following calculations seem to be justified:

Susquehanna ultra-clay, heated to 110°, absorbed 93.0 cc. NH_3
Susquehanna clay soil, heated to 110°, absorbed 27.7 cc. NH_3
Susquehanna clay soil, heated to 1130°, absorbed 1.4 cc. NH_3

Deducting 1.4 cc. NH_3 absorbed by material, presumably not colloidal, from 27.7 cc. absorbed by the unaltered soil leaves 26.3 cc. absorbed by the colloid of the soil. Therefore, if the pure colloid absorbs 93.0 cc. NH_3 and there is sufficient colloid in the soil to absorb 26.3 cc. NH_3, the colloidal content of the soil must be 28.3 per cent.

Absorption of dyestuffs and calculation of colloidal content. A gram sample is shaken up with 40 cc. of distilled water in a large test tube. A 0.1 *N* sodium oxalate solution is then added until there is a slight excess over the amount required to precipitate the calcium. The tube is corked and placed in an end-over-end shaking machine for 15 min. to insure complete precipitation. The suspension is next treated with a certain small excess of 0.2 per cent *malachite green* solution. The mixture is made up to definite volume (70 cc.) with distilled water, and the tube again placed in the shaking machine for 1 hr. Five cc. of *N* NaCl solution are now added to flocculate the colloidal mat., and the tube is centrifuged in a large mechanical analysis machine until the supernatant liquid is perfectly clear. This liquid is compared in a Duboscq colorimeter with a standard solution of dye to which have been added all of the reagents contained in the other.

Two complete series of Susquehanna clay soil samples were heated as previously described under absorption of ammonia; in fact, the samples for this work were heated in the same furnace and at the same time with the clay pellets in order to be sure the conditions were exactly the same. The dye absorption determinations were then made as above described, with the following results:

Susquehanna Clay Soil

(1 g. of soil, weighed after heating, was used in all determinations)

Weight of Dye Absorbed

Temp. °C	First series 1	2	Second series 1	2	Average wt.	Aver. loss of sample on heating
110	0.0358	0.0360	0.0352	0.0358	0.0357	0.000
190	0.0344	0.0338	0.0344	0.0342	0.0342	0.003
265	0.0200	0.0200	0.0203	0.0197	0.0200	0.005
374	0.0194	0.0202	0.0204	0.0198	0.0200	0.010
522	0.0	......	0.0194	0.0196	0.0195	0.055
673	0.0190	0.0185	0.0197	0.0197	0.0192	0.064
844	0.0	......	0.0105	0.0111	0.0108	0.065
1130	0.0018	0.0015	0.0019	0.0019	0.0018	0.065

Calculation of amount of colloid in Susquehanna clay soil from data obtained by dye absorption method.

Susquehanna ultra-clay, heated to 110°, absorbs 0.1196 g. dye
Susquehanna clay soil, heated to 110°C, absorbs 0.0357 g. dye
Susquehanna clay soil, heated to 1130°C, absorbs 0.0018 g. dye

Deducting the 0.0018 g. dye absorbed by material, presumably not colloidal, from 0.0357 g. dye absorbed by the unaltered soil leaves 0.0339 g. dye absorbed by the colloid of the soil. Therefore, if the pure colloid absorbs 0.1196 g. dye, and there is sufficient colloid in the soil to absorb 0.0339 g. dye, the colloidal content of the soil must be 28.3 per cent. This is exactly the same result as was obtained by the ammonia absorption method.

The results were further checked by mixing pure ultra-clay with weighed portions of soil in which the colloid had been entirely destroyed. Further investigation is promised to determine whether this method of determining colloidal content of clays is generally applicable. ED.

18. A study of the sintering process. K. ENDELL. Tech. Hochschule, Charlottenburg. *Met. u. Erz.*, **18**, No. 8(1921), 10 pp.—After a discussion of the nature of the various processes involved in sintering the author describes the Leitz thermal microscope arranged for studying materials up to 1500°C. The following exp. methods are suggested for ascertaining the nature and mechanism of the sintering process in any given case: (1) Microscopic exam. of the intermediate and final products resulting from calcination at different temps. (2) Microscopic obs. of the sintering process with the thermal microscope. (3) Det. of the amts. of sol. and insol. material after calcination. (4) Det. of the heating curve. ED.

19. Ultramarine blue. SAUVEGEOT. *Rev. prod. chim.*, Apr. (1921); *Tonind. Ztg.*, **45**, 494–5(1921).—The raw materials used in the production of u. blue are kaolin, sulphur, siliceous soil or kieselguhr, soda ash, caustic soda and sodium sulphate. They should be free from impurities especially iron and lime and should contain less than 0.5% Fe_2O_3 since more would produce a dark blue color. Lime acts as a flux and when more than 0.2% is present it causes the product to become sharp and brittle. The kaolin should be white and have a soapy feel. The kaolin should be dehydrated before use. Quartz powder is often used although it is difficult to get into solution and imparts to the product a violet or reddish cast. Kieselguhr may be used to a limited extent together with the quartz. It is desirable since it goes into solution easily but it is too bulky. The S should contain not more than 0.10–0.15% ash and should be free from As. The NaOH should be free from sulphates, chlorides, lime and iron. Rosin and tar are used for reduction purposes. Sawdust and fine coal may also be used. Usually two mixts. are made, one containing no quartz which is unstable and another containing quartz which is stable. Stable blues should be resist. to alum, Al_2O_3 and $C_2H_4O_2$. The following table gives the compositions of numerous shades of blue:

	A	B	C	D	E	F
Raw kaolin	540	325	326	430	524	430
Dried kaolin	...	205	150	...	...	...
Quartz powder	...	...	56	90	...	...
Kieselguhr	...	...	...	...	...	100
NaOH	8	6	6	5	5	3
Cal. soda	538	430	356	384	390	386
Sulphur	268	374	450	440	450	434
Tar	...	...	46	60	50	52
Charcoal	46	60	10	...	...	...
Sawdust	...	...	...	...	...	16

A produces a bright light blue with a greenish tinge, B a light blue, but darker and not as green as A, C a stable blue with a reddish violet tinge, D a stable blue with a reddish tinge, E an unstable blue, F a blue with a violet tinge. The mixts. are ground in a 1400 kg. ball mill for 3 hrs. at 60–70 R.P.M. In the crucible process for making u. blue, crucibles 30 cm. high with 1 cm. walls are used having a capacity of 5 kgs. The crucibles have a cover containing a hole. They are placed in an oven in groups of five. The furnace is fired rapidly for the first 2 hrs. since rapid firing produces a bright color. The crucible becomes red and the sulphur burns through the holes in the tops of the crucibles. The flame remains about 12–15 cm. long for about 7–8 hrs. after which it sinks to 1 cm. showing that the reaction is completed. The furnace is now allowed to cool until the crucible becomes a dull red after which the oven is sealed air tight. A large influx of air at this point would change the blue to white. The proper firing temp. is between 750–800°C. The oven is opened about 6–7 das. after the completion of the burn. Muffle furnaces may be used instead of crucibles and fired in a similar way.

H. G. SCHURECHT

20. Further development of the plastometer and its practical application to research and routine problems. HENRY GREEN. N. J. Zinc Co. *Proc. Am. Soc. Testing Materials*, **20**, II, 451–94(1920).—In the plastometer previously devised by Bingham and Green (*C. A.* **14**, 1047), the container is modified so that the material under test on being forced through the capillary tube at known pressures, displaces air at a rate which is measured by a very sensitive gaseous flow meter. The instrument gives mathematical definition to the character of plastics and is applicable to *degree of plasticity of clays*, particle size, etc. The instrument modifications are described in detail, mathematical detn. of the yield value factor, and graphs and tables of results presented. Bingham in his discussion of the paper shows that it is theoretically possible to measure plasticity by making only 2 measurements of flow through a single capillary. F. A. WERTZ (*C. A.*)

21. Suggestions for calibrating base metal thermocouples by the freezing point method. KIRTLAND MARSH. *Chem. Met. Eng.*, **24**, 1071(1921).—Recommended the use of an iron protective tube in calibrating when molten tin, zinc and aluminum are to be used. The tube is heated to 900 deg. F. and then dipped into a mixt. consisting of one part powdered graphite or ordinary plumbago to two parts water. This produces a protective coating on the tube. When copper is to be used as the calibrating metal a second coating is produced by dipping the graphite coated tube into a mixture of one part by volume slaked lime and one part water. This prevents oxidation of the graphite at the temperature necessary for melting copper. The tube can be cleaned and used repeatedly. The pure metals required can be secured from the Bureau of Standards. H. F. S.

22. Colloid chemistry and its general and industrial applications. F. G. DONNAN AND COMMITTEE. *Rept. Brit. Assoc. Advancement of Science*, **1920**, 1–154A; cf. *C. A.*, **13**, 1784.—The third of this series of excellent reports,

including the following subjects: Soap, ultramicroscopy, soly. of gases in colloidal solns., elec. charge on colloids, imbibition of gels (Tanning), bread making, photography (including collodion), cellulose esters, petroleum, asphalt, varnishes, paints and pigments, *clays and clay products.*

JEROME ALEXANDER (*C. A.*)

23. **Ultramicroscopy: Degree of dispersion—measurement with the ultramicroscope.** GEORGE KING. *Third Rept. on Colloid Chemistry, British Assoc.*, **1920**.—Discusses concn., size, shape, and internal structure of the dispersed phase, also a solid, liquid and gaseous continuous phase.

JEROME ALEXANDER (*C. A.*)

24. **The crystal structure of magnesium oxide.** RALPH W. G. WYCKOFF. Geophys. Lab. *Am. J. Sci.*, (5) **1**, 38–52(1921); cf. Davey and Hoffmann, *Phys. Rev.*, **15**, 333(1920).—An attempt is made to get a unique soln. for the structure of MgO as an example of the application of the more general method of studying the structures of crystals which arises from the uses of the theory of space groups. With the aid of X-ray spectrum measurements and Laue photographs it is shown that the "sodium chloride" arrangement is the only simple one that is possible, though there are more complicated groupings that agree equally well with the existing data. R. W. G. W. (*C. A.*)

25. **Clays and clay products.** A. B. SEARLE. *Third Rept. on Colloid Chemistry, Brit. Assoc.*, **1920**.—A very extensive (40 pp.) and suggestive discussion from the colloid-chemical point of view.

JEROME ALEXANDER (*C. A.*)

26. **The electrical charge on colloids.** J. A. WILSON. *Third Rept. on Colloid Chemistry, Brit. Assoc.*, **1920**.—A brief discussion.

JEROME ALEXANDER (*C. A.*)

27. **Fundamentals of the theory of color measurement.** W. OSTWALD. *Z. tech. Physik.*, **1**, 173–5, 261–71(1920); cf. *C. A.* **15**, 739.—A discussion of the theory and use of Oswald's chrometer. D. MACRAE (*C. A.*)

28. **Georgia kaolins to be studied.** ANON. *Chem. and Met. Eng.*, **24**, 1120(1921).—The Georgia kaolins are to be the subject of a special study to be undertaken by the Bureau of Mines under a coöperative agreement with the Central of Georgia R. R. These white clays of Georgia have been used with some success in ceramic industries, and it is believed that means can be found for a very much more extensive use of them if economical methods can be found for ridding them of impurities. H. F. S.

29. **Report of the ceramic division.** JOSEPH KEELE. *Summary Report, Can. Dept. Mines*, No. **542**, 102–9(1920).—The occurrences and properties of fire, pottery and brick clays in eastern Ontario are described. **Structural materials in Dundas, Stormont, and Glengary counties, Eastern Ontario.** J. KEELE AND L. H. COLE. *Ibid.*, 114–27.—Results of physical and firing tests of 15 clays and granulometric analyses of 13 sands are tabulated. **Pottery clays.** MARY E. YOUNG. *Ibid.*, 127–34.—Pottery clays and methods of testing and handling are described. Methods of making glazes, enamels and color decorations are given, also the occurrences of pottery clays in the Canadian provinces. L. W. RIGGS (*C. A.*)

White Ware

30. **Investigation of the cause of "blowers" in solid porcelain sanitary ware....and the cure.** R. H. Minton. *The New Jersey Ceramist,* **1,** 27 (1921).—The "blowers" manifest themselves by lifting the glaze like fish scales; or quite often glaze scales are blown entirely free of the body. They vary in size ranging from tiny "ticks" to holes sometimes as large as $^3/_4''$ in diameter. There are two forms. In one form small particles of quartz or granitic stones blow off the glaze scales and leave a tiny hole in the center. The second form always shows a black center. The cause of the latter is iron pyrites which give rise to the trouble because of improper methods of firing. The author demonstrated this experimentally. He concludes that "blowers" will always result when pyrite is present in the form of particles $^1/_8''$ in diam. or larger and that they will be caused even by minute particles if the firing conditions are improper. Proper firing conditions should be about as follows: 1—Allow sufficient time for water-smoking so that all the ware is properly prepared for oxidation, when that period arrives. 2—When cone 020 is reached, allow time for complete oxidation and continue slow firing up to cone 012. 3—When cone 1 is reached, discontinue firing until the top heat has somewhat settled, and avoid heavy reduction during high fire. 4—A draft gauge should be used and the draft kept under 5 mm.

C. W. Parmelee

31. **Locating most favorable composition of body and glaze.** P. H. Swalm. *The New Jersey Ceramist,* **1,** 51(1921).—S. advocates a systematic investigation by each mfgr. of his body and glaze under his own operating conditions in order to discover their limitations as affected by type of kiln, kind of fuel and method of firing. C. W. Parmelee

32. **Porcelain.** A. V. Bleininger. *The New Jersey Ceramist,* **1,** 17 (1921).—A general discussion of different types of porcelain, the changes which take place in the firing of such bodies and a few of the defects of such wares. C. W. Parmelee

33. **Practical points on erection and care of chemical stoneware apparatus.** Ismar Ginsberg. *Chem. Age* (N. Y.), **28,** 252–3(1920).—A description of methods of erecting chem. stoneware app. in the plant and a discussion of points in their care, of compn. of cements, etc., illustrated with diagrams.

Ismar Ginsberg (*C. A.*)

34. **A new colorimeter for white pigments and some results obtained by its use.** A. H. Pfund. *Proc. Am. Soc. Testing Materials,* **20,** II, 440–50 (1920); cf. *C. A.* **14,** 1251. (*C. A.*)

35. **Luster glazes.** Anon. *Keram. Rundschau,* **29,** 197(1921).—The proper temp. to produce lusters with naphthaline is 2 cones lower than the softening temp. of the glaze. Hence a glaze maturing at cone 02a and having a softening point between cones 012–010 will take a luster at cones 014–017. If the temp. is too high the glaze will blister and if too low it will not take a

luster. Paper, sawdust, tar, etc., may be used in the place of naphthaline to produce the desired reducing atmosphere. This method of luster decoration is employed with those glazes containing reducible oxides as copper oxide, etc. H. G. SCHURECHT

36. **The production of the red brown salt glaze on stoneware.** W. SCHUEN. *Tonind. Ztg.*, **45**, 249–50(1921).—When stoneware is fired the ferric compounds are changed to ferrous imparting to the body a gray color. The color is also gray directly after the salt glaze has been applied since this glaze is transparent. Considerable care is required to change the glaze to the desirable red-brown color. After the glaze has been applied the kiln is allowed to cool until the kiln atmosphere is distinctly oxidizing, after which the fire holes are closed to prevent rapid cooling. This oxidizing soaking period changes the gray ferrous compounds to the red-brown ferric compounds. H. G. SCHURECHT

See also No. 58.

Glass

37. **Glass faults, causes and prevention, functions and applications in the glass technique of our day.** C. J. STAHL. *Glashütte*, **4**, 819(1920).—"Bad glass" for one purpose may have a desirable property for some other application, as for artistic effects. WM. M. CLARK

38. **British scientific glass industry.** EDWARD AUINE. *J. Soc. Chem. Ind.*, **40**, 6–7R(1921).—A brief history of the development of the lab. and optical glass industry in the British Empire during the war, directed as an argument for protection against foreign competition. D. E. S. (*C. A.*)

PATENTS

39. **Coating glass to prevent accumulation of drops of water.** J. H. T. ROBERTS. U. S. 1,369,708, Feb. 22. Accumulation of drops of moisture on glass is prevented by coating the glass with a thin layer of gelatin, agar, casein or similar transparent material. (*C. A.*)

40. **Glass-drawing apparatus.** JOHN R. SCOHY. U. S. 1,372,044, March 22, 1921. In combination with a glass furnace and a dog-house, a glass segregating apparatus consisting of a deep inverted pot having a central opening in the top thereof, and a sloping exterior surface around the opening and a cylindrical shield having an edge surface conforming to the said sloping surface and adapted to fit the sloping surface and of a length sufficient to reach from the submerged pot to the top of the dog-house, the dog-house being so constructed as to leave unobstructed the said opening of the submerged pot.

41. **Glass-grinding machine.** EDWARD A. RYON AND ANNA T. RYON. U. S. 1,372,553, March 22, 1921. A glass grinding machine having a horizontally rotatable and longitudinally movable ware holder, gearing therefor, clutch mechanism for connecting the gearing with a source of power having a cone shaped terminal and a power driven cutter having engaged and disengaging mechanism operable by the terminal in conformity with the clutch mechanism.

42. **Manufacture of decorative glass, porcelain, or the like.** GORO SATO, Sakura, Japan. U. S. 1,372,555, March 22, 1921. A process of producing decorative glass, porcelain and the like, characterized in that thin sheets or patches of the crust or shell of shell-fish are prepared by cleansing the crust or shell, making it thin by grinding, mounting it by means of an adhesive on fibrous paper, crushing it and cutting into pieces or patches, and applying these pieces or patches by means of a suitable binder or adhesive to portions of the glass, porcelain or the like for the purpose specified.

43. **Apparatus to be employed in the manufacture of hollow articles of glass.** ALEXANDER FERGUSON, England. U. S. 1,371,085, March 8, 1921. In apparatus for manufacturing glassware, a forehearth, or the like, to contain a supply of molten glass, a rotable wheel mounted above the hearth, a series of receptacles arranged around the wheel and having open ends presented at the periphery of the wheel and adapted to enter the glass on the hearth, a plunger working in each receptacle, and means for operating the plungers successively in one direction to draw a charge of molten glass into each receptacle as it enters the molten glass on the forehearth, and means for successively operating the plungers in the opposite direction after the receptacles have the molten glass left to expel the charges from the receptacles, together with means for presenting successive molds to receive the expelled charges.

44. **Machine for the automatic and continuous manufacture of glass bottles.** GEORGE ORLANDO TAGUE, England. U. S. 1,373,272, March 29, 1921. In a machine for the manufacture of glassware, the combination with a mold charging and forming device and a separate blowing device, of an intermediate opposing gripping members movable up and down, and means for actuating the gripping members having an up and down movement independently of the corresponding movement of the gripping members whereby an article carried by one of the first mentioned devices is engaged and an article at the opposite side is simultaneously disengaged for deposit upon the other of the first mentioned devices.

45. **Scleroscope for testing the hardness or strain in glass due to insufficient annealing.** CLAUDE M. GARLAND. U. S. 1,370,738, March 8, 1921. In an instrument of the type described, a base, a blackened reflector mounted on the said base, two columns mounted on the base and adjacent to one end of the reflector, a frame slidably mounted on the said columns, a plurality of glass plates carried in the frame and a hood forming a part of the frame and shielding the plates.

46. **Method and apparatus for the manufacture of glass.** ALEXANDER FERGUSON, England. U. S. 1,371,084, March 8, 1921. In the manufacture of glass, the step of subjecting particles of glassmaking material to a vertical whirl in the presence of gas at smelting heat and leading the resultant viscous mass and the hot gas downward to a refining tank over the surface of the molten glass in which the gas passes.

47. **Apparatus for grinding or polishing plate-glass.** FREDERIC BARNES WALDRON, Eng. U. S. 1,370,246, March 1, 1921. Apparatus for grinding or polishing plate glass consisting of a series of rectangular tables in contact each with its neighbors forming a continuous support for the plates of glass and slidingly supported on fixed guides, a framework above the series of tables, a series of sets of runners on vertical shafts, bearings for the shafts attached to the framework, means for moving the series of tables continuously from one end to the other of the series of sets of runners, means for removing a table from the moving series of tables after it has left the last set of runners, and means for adding a table to the moving series of tables before the first set of runners, the sets of runners being so spaced apart as to permit of the effective washing away of the abrasive between any two sets using different grades.

48. **Apparatus for turning over sheets of glass to facilitate working on both sides of the sheets.** GEORGES HENRI LEON DEBAECKER, Netherlands. U. S. 1,371,868, March 15, 1921. A turntable for handling glass sheets and the like, comprizing an invertable frame adapted to receive the sheets, and spaced sets of supporting bars associated with the frame and accommodating the sheet between them, the bars of each set being movable to expose the upper face of the sheet for operations thereon while it rests upon the bars of the other set. C. M. SAEGER, JR.

Cement, Lime and Plaster

49. **Tentative methods for chemical analysis of limestone, lime, and hydrated lime.** ANON. *Proc. Am. Soc. Testing Materials*, **20**, I, 626–33 (1920).—Weigh out 0.5 g. of the substance and in the case of limestone or hydrated lime ignite in a Pt crucible for 15 min. or more with a blast lamp. Transfer to an evaporating dish, mix to a thin paste with H_2O, add 5–10 cc. of concd. HCl and digest until soln. is complete. Evap. to dryness. Treat the residue with 15–20 cc. HCl (1:1), filter and wash the SiO_2. Repeat the evapn., unite the ppts. of SiO_2, ignite, and weigh. For great accuracy, volatilize the SiO_2 with HF. Ppt. Al and Fe as hydroxides from the filtrate with NH_4OH in the usual way. Reppt., ignite, and weigh as $Fe_2O_3 + Al_2O_3$. Fuse the combined oxides with 3–4 g. of $NaHSO_4$, dissolve in dil. H_2SO_4, evap. to fumes, dil. with H_2O, filter any sepd. SiO_2, ignite, weigh, and add to the value obtained above. Reduce the Fe in the filtrate with H_2S, boil out the excess, and titrate the Fe with $KMnO_4$. Calc. the Al_2O_3 by difference.. Det. Ca in the filtrate from the hydroxide pptn. by pptg. with $(NH_4)_2C_2O_4$ and NH_4OH in the usual way. Ignite to CaO, dissolve in HCl, dil. to 100 cc., add NH_4OH in slight excess, and filter out any $Al(OH)_3$, correcting the value obtained above. Reppt. the Ca as above and either ignite and weigh as CaO, or titrate the CaC_2O_4 with $KMnO_4$. In the latter case, wash the ppt. from the paper with hot H_2O, add 50 cc. dil. H_2SO_4 (1:10), dil. to 150 cc., heat to 85° and titrate to a pink color. Then add the filter paper and complete the titration. Total volatile matter is detd. by igniting a 1-g. sample over the blast lamp. To det. mechanical moisture, weigh a 1-g. sample upon a tared watch glass and

heat at 120° for 2 hrs. Det. SO_3 in a 2-g. sample by dissolving in dil. HCl and pptg. as $BaSO_4$. Det. CO_2 according to the method given in *U. S. Geologic Survey Bulletin*, **422**, whereby a 0.5-g. sample is treated with dil. HCl and the evolved CO_2 is passed though a reflux condenser and then through $CaCl_2$, anhydrous $CuSO_4$, $CaCl_2$, and is finally absorbed by soda lime.

S. G. SIMPSON (*C. A.*)

50. Technical analysis of Portland cement. W. O. ANDREWS. *J. S. African Assoc. Anal. Chem.*, **3**, 3–5(1920).—Details are given of the usual methods for the detn. of SO_3 and insol. matter, SiO_2, Fe_2O_3, Al_2O_3, CaO and MgO. G. W. STRATTON (*C. A.*)

51. Central research laboratory for the cement industry. J. BIED. *Rev ing.*, **28**, 1–7, 61–7(1921).—Brief review of the present state of our knowledge of hydraulic cements and hints on the progress which might result in the cement industry from properly conducted research, to show the importance and advizability of establishing a central research lab. to be supported by the French cement industry. A. P.-C. (*C. A.*)

52. Specifications for the color of gypsum plasters. WARREN E. EMLEY AND CHARLOTTE G. FAXON. *Chem. Met. Eng.*, **24**, 1054(1921).—The methods for measuring color described in detail in Bureau of Standards, *Technologic Papers* **92** and **167** are applied to gypsum plasters and give a very accurate method for classifying these according to color. The requirements suggested for a "white" plaster are, (1) the log. of the diffused reflection for average sunlight shall be numerically less than 0.147, and (2) the ratio of the reflection of blue light (wave length = 436 $\mu\mu$) shall be not less than 0.8. For a "gray" plaster, requirement 1 is changed to read "more than" instead of "less than." Requirement 2 is the same for both white and gray plasters. H. F. S.

53. Lignite brick fuel. ANON. *Rev. Mat. Constr. Trav. Pub.*, No. **141**, 95B (1921).—Lignite brick of average composition C 55%, water 13%, ash 6% and volatile combustibles 26% gives 4800 cal. of heat. It may be used as fuel for all purposes, and is especially of use for heating *lime kilns*. The larger volume of volatile matter continuously removes the CO_2, and thereby accelerates the reaction $CaCO_3 = CaO + CO_2$. LOUIS NAVIAS

54. Fire tests on building columns. S. H. INGBERG, H. K. GRIFFIN, W. C. ROBINSON AND R. E. WILSON. *B. S. Tech. Paper*, **184**.—An investigation of the resistance of cols., loaded and exposed to fire or to fire and water, with a record of characteristic effects, conducted in coöperation with the Associated Factory Mutual Fire Insurance Companies and the National Board of Fire Underwriters, at the Underwriters' Laboratories.

The fire exposure was produced by placing the col. in the chamber of a gas-fired furnace, whose temp. rise was regulated to conform with a predetermined time-temp. relation. Measurements were taken of the temps. of the furnace and test col. and of the deformation of the latter due to the load and heat. The test cols. were designed for a working load of approximately 100,000 lbs. The working load was maintained constant on the col. during the test, the efficiency of the col. or its covering being determined by the length

of time it withstood the combined load and fire exposure. In the fire and water tests, the col. was loaded and exposed to fire for a predetermined period, at the end of which the furnace doors were opened and a hose stream applied to the heated column, the severity of the test being regulated to correspond with the degree of resistance developed by the corresponding type of col. in the regular fire tests. The results of the tests were summarized in terms of hrs., and minutes of fire resistance afforded by the different types of cols. and protections tested. The resistance period is taken as $^2/_3$ of the average time to failure in the fire tests.

The resistance periods thus derived vary from 10 min. for unprotected structural steel cols., to 8 hrs. for similar cols., covered with 4 inch thickness of concrete made with fire resistive aggregates. Filling the reentrant portions or interior of structural steel columns with concrete gave them resistance periods ranging from $^1/_2$ hour to 3 $^1/_2$ hrs., depending on the size and shape of the col. and the concrete aggregates employed. Single-layer protection of plaster on metal lath applied to struct. steel cols., gave a $^3/_4$ hr. resistance, and double layer, with airspace between, 1 $^1/_2$ hrs. Two inch concrete protection on struct. steel gave resistance periods from 1 to 4 hrs., depending on the aggregate. The concrete made with sand and pebbles high in silica (chert and quartz) developed disruptive effects on exposure to fire, which is ascribed (1) to points of abrupt vol. change existing for chert as low as 210°C and for quartz at 573°. (2) To disruption of the pebbles from expulsion of chemically combined occluded water. Concrete made with trap rock, granite sandstone, or hard coal cinder aggregate proved superior to that made with siliceous gravel. The highest resistance obtained with concrete made with dolomitic limestone and calcareous sand. The 4 in. concrete protections developed resistance periods from 2 $^1/_2$ to 8 hrs., variation with the aggregate being similar to that for the 2 in. protections. Hollow clay tile on structural steel cols. gave periods from 1 to 3 hrs., depending on type of clay and method of application. Tile made from semi-fire clay burnt to medium hardness developed greater freedom from cracking and spalling than any other tile tested. Hard burnt semi-fire clay tile evidenced greater effects from fire exposure, and with surface clay and shale tile these disruptive effects were very marked. Little or no difference in resistance was noted as between the 2 and 4 in. thickness of hollow tile, the time to failure being dependent on the area of solid material rather than on the thickness of the air space. Filling the interior with concrete or tile appreciably increased the resistance and stability of the covering, and interior metal ties were found superior to outside wire ties in holding the tile in place. Solid clay brick set on end and edge to form a solid covering about 2 $^1/_2$ in. thick outside of the steel proved somewhat unstable on exposure to fire and developed a resistance period of only 1 hr., while with brick laid flat in the usual manner to form a 4 in. covering, 5 hr. fire resistance was developed. Solid gypsum block, 2 in. in thickness, laid outside of flanges and edges of struct. steel cols. and with space between blocks and flanges filled with gyp. mortar, gyp. blocks

or poured gyp. filling, gave 1 1/2 hr. resistance, and similar coverings made with 4-in. solid blocks gave 3 1.2 hr. resistance, failure being due in all cases to shrinking, checking and disintegration of the blocks which caused them to fall off and expose the steel. Reinforced concrete cols. with 2 in. integral concrete protection, gave 5 hr. resistance made with trap rock aggregate, and 8-hr. resistance made with limestone aggregate. H. F. S.

PATENTS

55. Manufacture of Keene's cement. WILLIAM HOSKINS. U. S. 1,370,968, March 8, 1921. The method of producing Keene's cement stock which consists in reducing gypsum to a relatively fine state of subdivision passing the subdivided product continuously at a uniform rate through a rotary internally fired kiln, and adding hydrate of lime to the burnt product in amount sufficient to neutralize all acidity.

56. Manufacture of slow-setting cement. FABIO FERRARI, Rome, Italy. U. S. 1,372,015, March 22, 1921. A slow setting calcareous cement free from binary calcium compounds of alumina or iron generally used, which is prepared by converting into slag a raw mixture of the ordinary type used for Portland cement, in which the proportion between the oxide Fe_2O_3 and Al_2O_3 is comprised between 1 and 1.563. C. M. SAEGER, JR.

Enamels

57. The new Meurer enamel spraying process. ANON. *Sprechsaal*, **54**, 490–91(1921).—Meurer with the aid of the Schoop patents developed a spray whereby enamel is molten and sprayed on metals, etc. The spray has attached to it a glass container in which fine ground enamel similar to that used for kiln fired enameling is placed. This powder is drawn out of the container by suction and mixed with compressed air or oxygen which is forced through one jet of the burner. Combustible gases as hydrogen, acetylene or luminating gas are forced out of another jet. With this spray a white enamel as well as others may be applied without a ground coat. Enamels contain potash, soda, lime, fluorspar, cryolite and clay which increase their elasticity. The ground coats used with kiln fired enamels are lacking in these constituents and therefore produce enamels with inferior elasticity. The sprayed enamels are more resistant to blows and sudden temp. changes than the kiln fired enamels which may be partly due to the fact that they can be applied thinner than the kiln fired enamels. In firing enamels in a muffle kiln the carbon, silica, manganese, and phosphorus of the iron are liberated causing reducing conditions. This is especially harmful to reducible oxides such as Sn, Zn, Pb and Cu oxides. By the new method the source of this trouble is avoided. This method may also be used for repairing enamel ware which heretofore has caused many costly delays. In repairing with the spray the combustible gas alone is first used to slowly heat the ware to be repaired. This is done by gradually localizing the heat around the area to be repaired and forcing the molten enamel against the chipped portion. The piece is then allowed to cool slowly by covering the same with an asbestos board.
H. G. SCHURECHT

58. Preparation of glazes and enamels. J. B. Shaw. *New Jersey Ceramist*, **1**, 52(1921).—Red specks are developed in lead glazes byparticles of organic matter such as wood fibre from linings of ball mills, or particles of woody matter from ball clay. The weighing of (large) glaze batches is a useless refinement unless the moisture content of the material is regularly determined and taken into consideration. [The alternative method must be assumed to be proportioning by volume. Abs.] The tempering of glazes should be done during the grinding, and care should be used to proportion the water, plastic clay and tempering agent so as to prevent settling of the heavier constituents. 5 lbs. of ball clay when properly tempered with a suitable flocculating agent is as effective in floating heavy glaze ingredients as 10 lbs. of clay without such flocculating agent. The author is opposed to the practice of preparing large batches of glazes and storing because of the settling of the ingredients and the probability of inadequate stirring before drawing off for use. The importance of thoroughness in the mixing of the ingredients for frits is emphasized. Failure to observe this precaution may occasion a serious loss in the opacity of enamels containing tin oxide or antimony oxide. This applies in some degree to cryolite and other fluorides. One of the essentials in the successful use of antimony oxide in enamels is care in mixing it most thoroughly with the other ingredients before fritting. Little success was attained until it was ground into a ball mill with part of the feldspar of the batch.

During the charging of the frit kiln, there is an appreciable loss of fine dust-like material which is sucked up the stack by the draft. This may be avoided by closing the stack damper before charging, or wetting the charge before introducing it into the furnace. The charge should be spread evenly in the furnace and stirred frequently. This prevents segregation and increases the speed of fusion. The writer has noted the development of specks in white enamels fritted in furnaces using fuel oil. He attributes these to particles of carbon from the fuel oil reducing lead in the frit.

C. W. Parmelee

Brick and Tile

59. Physical properties of building brick. F. Brick. *Rev. Mat. Constr. Trav. Pub.*, No. **139**, 49–53(1921).—Data from tests by Bureau of Standards.

Louis Navias

60. Straw-paper sheets for blocking up openings in kilns. C. Mira. *Rev. Mat. Constr. Trav. Pub.*, No. **141**, 84–85B(1921).—Sheets of straw-paper, 6 ft. × 3 ft. may be used to block up entrances to brick kilns. The sheet is impermeable to gases, and is inflammable. By pasting two sheets together along a 6 in. border a wider sheet may be obtained. It is held over the opening by pasting it on to the surrounding brick with flour-paste or clay slip, then by piling brick below and beside the sheet. Louis Navias

61. Enamelled brick. G. Briffe. *Rev. Mat. Constr. Trav. Pub.*, No. **141**, 87–90B(1921).—A simple layout for a small enamelled brick plant to produce 350,000 brick annually. No details. Louis Navias

See also No. 54.

Terra Cotta

62. The manufacture of architectural terra cotta. L. V. *Rev. Mat. Constr. Trav. Pub.*, No. **139**, 55–57B, No. **140**, 70–72(1921); see also previous articles in Nos. **133, 134, 135**(1921).—A history and detailed account of manufacture, taken presumably from American literature. LOUIS NAVIAS

BOOK REVIEWS

63. Technical methods of analysis. ROGER CASTLE GRIFFIN. Pp. 666 and 29 figures. McGraw-Hill Book Co., New York, 1921. This book is a laboratory manual, giving explicit directions for making chemical analyses. The methods selected are those which have given general satisfaction in commercial work. Assuming that the reader has had some experience as an analyst, the directions given can be easily followed. Besides the analytical directions, methods for physical testing are also given when these are necessary to establish the quality of the material. No attempt is made to give any theories or explanations. The scope of the work is very extended, including methods for the analysis of almost everything, organic or inorganic, which is an ordinary article of commerce. WARREN E. EMLEY

ACTIVITIES OF THE SOCIETY

New Members Received During June, July and August

Resident Associate

Aurien, George, 4070 N. Main St., St.Louis, Mo., Superintendent, Mississippi Glass Co.

Bloomfield, Howard W., Metuchen, N. J., Secretary, Treasurer, and Manager, New Jersey Clay Products Co.

Carspecken, H. L., Morgantown, W. Va., Manager, Mississippi Glass Co.

Douglas, Ralph J., Cincinnati, Ohio, Pottery Manager, The John Douglas Co.

Duhart, A. L., Port Allegany, Pa., Assistant Manager, Mississippi Glass Co.

Duval, A. M., 901 North Forest Ave., Brazil, Ind., Salesman, Manufacturers Equipment Co., Dayton, Ohio.

Farris, P. C., 9 W. Park St., Brazil, Ind., Superintendent, Hydraulic Press Brick Co.

Ford, George D., 104 Woodlawn Ave., Zanesville, Ohio, Ceramic Engineer, Mosaic Tile Co.

Franzen, Nick., Port Allegany, Pa., Manager, Mississippi Glass Co.

Grant, Frederic J., 134 Woodlawn Ave., Zanesville, Ohio, Mosaic Tile Co.

Greene, R. J., 156 W. Indiana Ave., Sebring, Ohio, Foreman, Gem Clay Forming Co.

Gutmann, Paul F., 4248 Blaine Ave., St. Louis, Mo., Assistant Superintendent, Mississippi Glass Co.

Hahn, Carl A., 2138 Blendon Place, St.Louis, Mo., Assistant Engineer, Parker Russell Mining and Mfg. Co.

Hall, F. P., 1758 Columbia Rd., Washington, D. C., Bureau of Standards.

Henry, Kenneth M., San Francisco, Cal., Illinois Pacific Glass Co.

Herrold, R. P., 955 Brighton Blvd., Zanesville, Ohio, Mosaic Tile Co.

Ichijo, Mokiji, c/o J. H. Ohyama, Woolworth Bldg., New York City.

Klaesius, Paul K., 3350 Scotten Ave., Detroit, Mich., Factory Superintendent, Wolverine Porcelain Enameling Co.

Koering, E. W., Crystal Ave., Vineland, N. J., Kimble Glass Co.

Lawler, John J., 839 Thomas Ave., Forest Park, Ill., Jas. H. Rhodes & Co.

Lord, N. W., Jr., 338 W. 8th Ave., Columbus Ohio, Ohio State University.

Maley, Wm. V., 315 W. Maryland Ave., Sebring, Ohio, Limoges China Co.

Miller, J. Walter, 634 Forest Ave., Zanesville, Ohio, Mosaic Tile Co.

Mills, Geo. P., 908 Chestnut St., Philadelphia, Pa., Electric Furnace Construction Co.

Montgomery, J. C., Sebring, Ohio, Superintendent, Limoges China Co.,

Morley, S. I., 246 East Ohio Ave., Sebring, Ohio, Sales Manager, Sebring Pottery Co.

Ramsdell, Lewis, S., 29 West St., Worcester, Mass., Norton Co.

Rhead, John, Hotel Columbus, Columbus, Ohio, General Manager, Sanitary Earthenware Specialty Co.

Robison, David V., 104 Woodlawn Ave., Zanesville, Ohio, Mosaic Tile Co.

Saunders, Lewis E., 262 Salisbury St., Worcester, Mass., Norton Co.

Schwier, Carl, 295 E. 4th St., Mansfield, Ohio, Mansfield Vitreous Enameling Co.

Scott, R. N., Old Hickory Clay & Talc Co., Paducah, Ky., Secretary-Treasurer.

Smith, C. B., 1010 Hancock St., Saginaw, W. S., Mich., Assistant Superintendent National Plate Glass Co.

Underwood, C. A., Valley, Wash., Superintendent, American Refractories Co.

Vieweg, George B., 494 Grand St., Morgantown, W. Va., Assistant Manager, Mississippi Glass Co.

White, Richard P., 121 S. Menard Ave., Chicago, Ill., Secretary-Treasurer, Union Stoneware Co.

Foreign Associate

Jacobsen, Carl, Malmogade 7, Copenhagen, Denmark, University of Copenhagen.

Knudsen, Rolf, Borgestad, Norway.

Lax, Thomas, Hunslet, Leeds, Yorkshire, England, Director, Lax & Shaw, Ltd.

Naganuma, Hikosaburo, Kamoike Works, Electric Railroad Co., Kagoshima, Japan.

Segsworth, R. F., 103 Bay St., Toronto, Ont., Canada, Feldspars, Ltd.

Corporation

Crescent Refractories Co., Curwensville, Pa.

General Ceramics Co., 50 Church St., New York City.

Johnson-Porter Clay Co., McKenzie, Tenn.

Kier Fire Brick Co., 2243 Oliver Bldg., Pittsburgh, Pa.

Mississippi Glass Co., 220 Fifth Ave., New York City.

Moore & Munger, 29 Broadway, New York City.

Niles Fire Brick Co., 165 E. Park Ave., Niles, Ohio.

Parker-Russell Mining & Mfg. Co., 603 Laclede Gas Bldg., St. Louis, Mo.

The Product Sales Co., 206 Water St., Baltimore, Md.

Reading Fire Brick Works, Reading, Pa.

Stockton Fire Brick Co., 915 Rialto Bldg., San Francisco, Cal.

NECROLOGY

Silas Carl Linbarger, for the past six years ceramic engineer of The Carborundum Company, Niagara Falls, N. Y., died at his home in that city Saturday, September 10th.

Mr. Linbarger was born at San Jose, Ill., September 21, 1892, was graduated from the Champaign (Illinois) High School and the University of Illinois,

class of 1915. After a short time as instructor at the University, he entered the employ of The Carborundum Company, where, on the death of Mr. L. B. Coulter, he was promoted to the responsible position of Ceramic Engineer, which position he filled until he succumbed to the ravages of a disease against which he has gamely fought for several years.

Although a young man, Mr. Linbarger carried responsibilities in his line of work usually borne by men of twice his years. In the field of refractories and abrasives he was an authority. His knowledge of grinding operations was a most comprehensive one.

Among his patents was one covering a crucible of graphite, clay and silicon carbide, used for melting metals. The crucible, now a commercial article, has proved to be more efficient and of longer life than the old-fashioned kind made of graphite and clay. This new crucible is not to be confused with that made of firesand, graphite and clay, of earlier origin.

Under Mr. Linbarger's direction there was also developed, the clay and silicon carbide mixture for making such articles as saggers. These known as "Carborundum Saggers" are used by ceramists engaged in the art of making both heavy and light porcelain ware, such as sanitary ware, spark plugs, etc. The greater strength of such saggers, coupled with their high thermal conductivity, make them extremely efficient and are a great credit to their inventor.

These developments alone would have been sufficient for one of his years, but they were not the whole of his work. Improved grinding wheels, both of silicon carbide and aluminous abrasives, refractory articles of special shapes for various industries, including electric furnace linings, gas retort linings and the like, have been the product of his mind, as director of the experimental work along such lines.

Mr. Linbarger was one of the younger trained ceramic men who were endeavoring to build up the American Ceramic Society, and he had been a member of several committees. The respect of his fellows is evidenced by his election as President of the N. Y. State Section of the society.

He leaves a widow Helen Garwood Linbarger and his mother Mrs. Rose Linbarger, living at Niagara Falls.

Services were held at St. Mary's Roman Catholic Church, Niagara Falls, Monday, September 12th, at which was gathered a large delegation from The Carborundum Company, the American Chemical Society and the American Ceramic Society, together with many personal friends. Interment took place at San Jose, Ill., his birthplace.

793

JOURNAL

OF THE

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EDITORIAL

THE TRIBUTE TO PROFESSOR ORTON

It is fitting that in the pages of the Society's JOURNAL there be made a permanent record of the work of the resolution committee in transmitting to Professor Orton the resolution of appreciation adopted by the Society at the Columbus meeting. The resolution itself was appropriately engrossed by Ralph Fletcher Seymour and was transmitted to Professor Orton by W. P. Gates, chairman of the committee. The text of the resolution, together with Chairman Gates' letter of transmittal and Professor Orton's acknowledgment are given in full below:

Chairman Gates' Letter of Transmittal

MY DEAR ORTON:

At last I have gotten the resolution engrossed and signed and it is now going into the frame and then to you. Really it was a hard resolution to write and I felt my inefficiency. Words can not express the esteem in which the Society holds you or their appreciation of the work you have done. Had you not entered into the field and shown your untiring energy as you did, the present condition of the clay working interests would have been far different than it is. When the history comes to be written

your part will be appreciated. Generally, the appreciation only comes when the man is dead but I am very glad that in your case there is wide appreciation now and there will be more and more as time goes on. As one who should do much and has done but little, I greet you as a master at accomplishment. Please remember, when you see the resolution, that it is but a weak expression of the esteem and love the whole Society has for you. Very honestly and sincerely— W. D. GATES, *Chairman*

The Resolution

WHEREAS, the American Ceramic Society, in Convention assembled at Columbus, Ohio, naturally recall memories of the first meeting held in the same place twenty-two years ago, and—

WHEREAS, it is remembered that the inception of this Society was from the mind of and directly due to the untiring effort and the winning personality of Edward Orton, Jr., who then gathered in the men to form it, and—

WHEREAS, for twenty years thereafter, and until his country demanded his services, Professor Orton worked untiringly and unselfishly, giving freely of his knowledge, his energy and his marvellous personality, to the growth and upbuilding of this Sosiety, and—

WHEREAS, the present condition of the Society is directly traceable to his generous and continued effort:

Now therefore, be it resolved that the heartfelt thanks of the Society be tendered him, as a testimonial of our appreciation of the great work he has accomplished, and as a token of the love and esteem we have for him. That this resolution be spread on on the records of the Society and an engrossed copy thereof be presented to Colonel Orton.

Done in Convention at Columbus, Ohio, February 23, A. D. 1921.

FORREST K. PENCE, *President*
CHARLES F. BINNS, *Secretary*
WM. D. GATES
F. W. WALKER } *Committee*
STANLEY G. BURT

Professor Orton's Letter of Acknowledgment

MY DEAR GATES:

The resolution has arrived and I was utterly unprepared for the beautiful work of art which has been prepared for me by yourself and your fellow committee men. I did not take the thing seriously at the time of the passage of the resolution thinking that it was just a momentary expression of good will on the part of my old friends, and that what I should receive would be a neatly written or possibly engrossed copy of it, but I never dreamed of the committee taking the time and trouble to prepare the beautiful and enduring testimonial which I have received, and am deeply moved by it in consequence of its unexpectedness. I shall keep it as long as I live, and it will be one of my dearest possessions. That and my Distinguished Service Medal which I won in the War and which I feel has given the stamp of approval of my military life, as this certificate gives the stamp of approval to my professional and technical life through a period of nearly a quarter of a century. The best efforts that I can make to thank you and the Committee and the Society will be utterly impossible, inadequate and unavailing, and so I shall not try, only say that I am doubly paid for whatever I have done for the American Ceramic Society from the fact that what I did was a pleasure and its own reward at the time.

With affectionate regards, I am

Yours very truly,

EDWARD ORTON, JR.

ORIGINAL PAPERS AND DISCUSSIONS

HUMIDITY SYSTEM OF DRYING TERRA COTTA[1]

By F. B. Ortman and H. E. Davis

ABSTRACT

A brief discussion of the theory of humidity drying is followed by a description of the construction and operation of a five room dryer installed above a tunnel kiln and supplied with automatic temp. and humidity control and air circulation. As compared with the older system having controlled air circulation only, the new dryer has been found to have the following advantages: (1) Reduced steam consumption; (2) 50% reduction in floor space; (3) 50% reduction in drying time; (4) Reduction in labor costs owing to elimination of a second handling of incompletely dried pieces; (5) Reduced losses from cracking and warping.

Introduction

The principles of humidity drying as applied to clay wares was first brought before the Society, in Volume 11, by Mr. E. D. Gates. His report dealt only with experimental data, but the results were promising and the principle the same as is applied in present day humidity dryers.

The next presentation of the subject was by Mr. W. A. Denmead, who went quite thoroughly into the subject in conjunction with certain manufacturers of drying equipment. After a very thorough search into the possibilities of humidity drying for clay wares, especially for tight porcelain bodies, his conclusions were all very favorable.

Instances were cited where the drying time was reduced from one month with losses, to 12 hours with practically no losses. The principle is the same as that applied in our dryer so we will not go into a discussion of it now, as it is brought out very fully in succeeding paragraphs.

[1] Received April 7, 1921.

Theory of Humidity Drying

Fundamentally, the successful drying of all hygroscopic materials, regardless of their nature, follows a definite theory which may be set forth as follows:

Consider a mass of any size and any thickness containing moisture uniformly distributed. Several considerations must be taken into account in order to accomplish its successful drying. In the first place, there must be a heating up period, during which no evaporating or drying is permissible.

This heating up period accomplishes two things. First, it heats the ware uniformly throughout its entire mass, and second, it increases the vapor tension of the moisture contained. This can not be accomplished with dry, hot air, therefore, high relative humidities must be maintained during this period.

After the material has been heated up and the vapor tension in the moisture has been raised to approximately the same as that of the surrounding air, the relative humidity of the surrounding air is gradually decreased, by increasing the temperature, and the drying period now begins.

The transfer of moisture from air to materials, or from material to air, depends upon the difference between the vapor tension of the two. If the vapor tension in the air equals that in the material, there can be no transfer of moisture in either direction. Hence, by gradually decreasing the relative humidity of the surrounding air, the vapor tension *difference* between air and material creates a condition that permits the regulated amount of moisture absorption by air from material.

Evaporation of moisture from the surface of the material, exerts a decided cooling effect, which lowers the vapor tension of the surface moisture and since, therefore, vapor tension tends to equalize wherever there is a difference, this automatically creates a condition which causes a transfusion of moisture from the interior of the piece to the surface. By gradually lowering the vapor tension of the surrounding air, this process of moisture transfusion from the center of the mass to the surface of the mass continues until the vapor tension throughout the entire mass is equal to the vapor tension of the surrounding air.

With equipment able to maintain these fundamental conditions there can be no unequal shrinkage or stresses and consequently, no warping or checking. Contrast the above with the old method of drying, where hot, dry air is blown directly against the piece, which is still cold. The effect of hot, dry air is to evaporate the moisture from the surface of the piece very rapidly, reducing the porosity and causing case-hardening. In addition to this, since evaporation means cooling and since rapid cooling and shrinkage takes place only on the surface of the mass, a condition is created that tends to check and crack the ware, and by reason of unequal strains set up, tends to promote warping. Furthermore, the old method prolonged the total drying period, since the case-hardening of the surface and resultant lower porosity of the material at this point, serves to imprison the water in the interior of the piece and to delay its transfusion to the surface where it can be picked up by the air.

Installation

The installation described below is that of the Northwestern Terra Cotta Company at Chicago. It consists of five rooms each 34 ft. long, 23 ft. 8 in. wide and 8 ft. 6 in. high, with a capacity of approximately 20 tons, wet weight. In the construction of these rooms, particular attention was given to making them as nearly air-tight as possible, and also to protecting all interior surfaces against possible deteriorating effect of humid atmosphere. Each room has one outside exposed wall. To guard against possible condensation, this wall is constructed of 13 inches of brick, 1 inch air space, 3 inches of hollow tile and 1 inch of hard cement plaster. The side and end walls and ceiling are also finished with 1 inch hard cement plaster, all of which is finally treated with 2 coats of clear minwax waterproofing.

Each box has two openings, 12 ft. wide, for loading and discharging. The doors are one piece, 3 ply, tin-clad fire doors and are handled on special patented hardware furnished by the Dry Kiln Door Carrier Company. By means of this device, the door when in place, rests with its entire weight against the jambs and lintel of the opening, reducing leakage to a minimum. When not in use, the doors may be lifted with great ease and swung clear of the wall and rolled to one side on an overhead track. (See figure 1.)

The rooms are laid out in 2 pairs and one single room. The equipment, consisting of fans, heater coils and control instruments, is located between the rooms of each pair and at the end of the single room. Each pair of rooms is served by one equipment with a separate equipment for the single room. The supply ducts and return ducts are located between the ceiling and roof beams.

Fig. 1.

All of the dry rooms are located directly over the Dressler Tunnel Kiln now in operation at the same plant. This is of considerable advantage by reason of the fact that the concrete floor of the dryer is always kept warm from the radiated heat of the kiln. (See figure 2.)

The apparatus for these rooms consists essentially of a bank of low pressure pipe coil heaters, and a separate bank of high pressure coil heaters and fan, especially designed galvanized iron duct distributing supply and return system, together with the necessary

fans and Carrier ejector nozzles for recirculating the air within the room. The return air duct system returns air to the return end of the heaters. There is also a steam spray jet situated in front of the high pressure coil heaters, and a temperature and

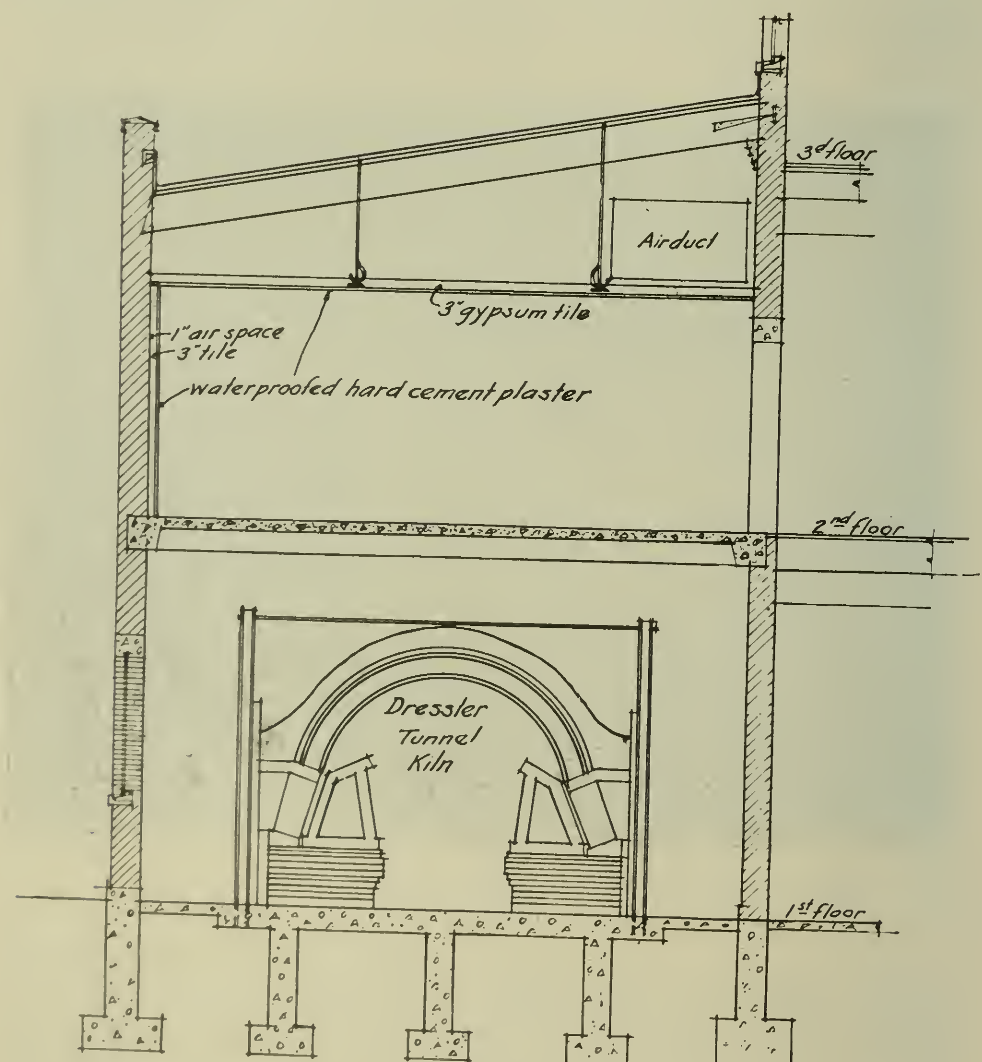


FIG. 2

humidity control system for controlling the temperatures throughout the drying stage and the relative humidity during the first heating up stage. Figure 3 shows the ejector nozzles.

Operation

Each of these rooms was designed to effect the removal of 5700 lbs. of water from a total of 40,000 lbs. of material, wet weight. This approximates 20% of moisture content, based upon the dry weight. The material is dried to approximately 5% moisture content, so that a total of 17% moisture, as compared with the dry weight, is removed in drying.

The schedule upon which these rooms are worked is as follows:

Three hours are allowed for the loading of the rooms. The material is loaded in tiers and handled in and out of the rooms by means of an industrial lift truck. Eighteen hours' time is allowed for the period of drying and three hours allowed for unloading the room.

Fig. 3.

After the material is loaded in the room the low pressure coils are turned on and the fan started up. All other operations during the period are entirely automatic. The control is effected by means of hygrostats and thermostats set for given conditions, which operate through the medium of compressed air on diaphragm valves, which in turn operate on heater coils or steam spray jets as the case may be. The compressed air is supplied from a small central air-compressor plant.

The circulation of the air within the room is accomplished by means of the ejector nozzles as follows; Air from the fan is forced through these nozzles, at a very high velocity, causing an ejector effect on the air within the room, picking it up and mixing it with the hot air direct from the heater, and continually recirculating

it through the material. In order to facilitate the recirculation, a space is left between the material and the front and rear walls and ceiling. The effect is to produce practically a uniform condition of air circulation, temperature and humidity throughout the entire room.

During the first three hours, the material is allowed to heat up in an atmosphere of relatively high humidity. High relative humidity is maintained by means of a steam jet discharging directly into the air in circulation and regulated by a hygrostat. As soon as the air in circulation within the room has reached a definite relative humidity, the steam spray jets are shut off automatically. This continues until the ware temperature within the room has reached a point at which actual drying is to start. This consumes a period of approximately three hours. During this period, practically no moisture is evaporated from the material and by maintaining a high relative humidity, full advantage is taken of not only the sensible heat, but also of the latent heat to heat up the material within the room and to raise the vapor tension of its moisture so as to prepare it for drying. When a room temperature, previously determined by experiment, indicates that the ware has reached the drying temperature, a thermostat automatically shuts off the steam supply to the steam spray, irrespective of the hygrostat, and also admits steam to the high pressure steam coils. The temperature then gradually rises and the relative humidity falls off, thus creating the condition of vapor tension difference necessary for the transfer of moisture from the material to the air. This condition is allowed to continue until the safe maximum temperature permissible within the room is reached. Then a thermostat set for this temperature automatically regulates the steam admission to the high pressure steam coils and maintains a minimum temperature of 185° through the remainder of the drying period.

Further explanation of the process of drying may be had by referring to figure 4, which shows a curve obtained by plotting the difference in the wet and dry bulb temperature depressions against the time for the entire period of drying, and another curve showing the loss in weight of a sample piece placed within the dryer, for the same period.

It will be noticed that during the first three hours, no drying whatever took place. At the end of this heating up period, the steam spray was automatically shut off and the high pressure heater coils turned on, and from then on the drying proceeded quite rapidly as the depression increased (relative humidity decreased) until at the end of $14^1/_2$ hours, the testpiece was dry and lost no more weight. In accordance with the regular schedule however, the drying was continued for the entire 18 hour period to insure complete drying of all pieces in the box.

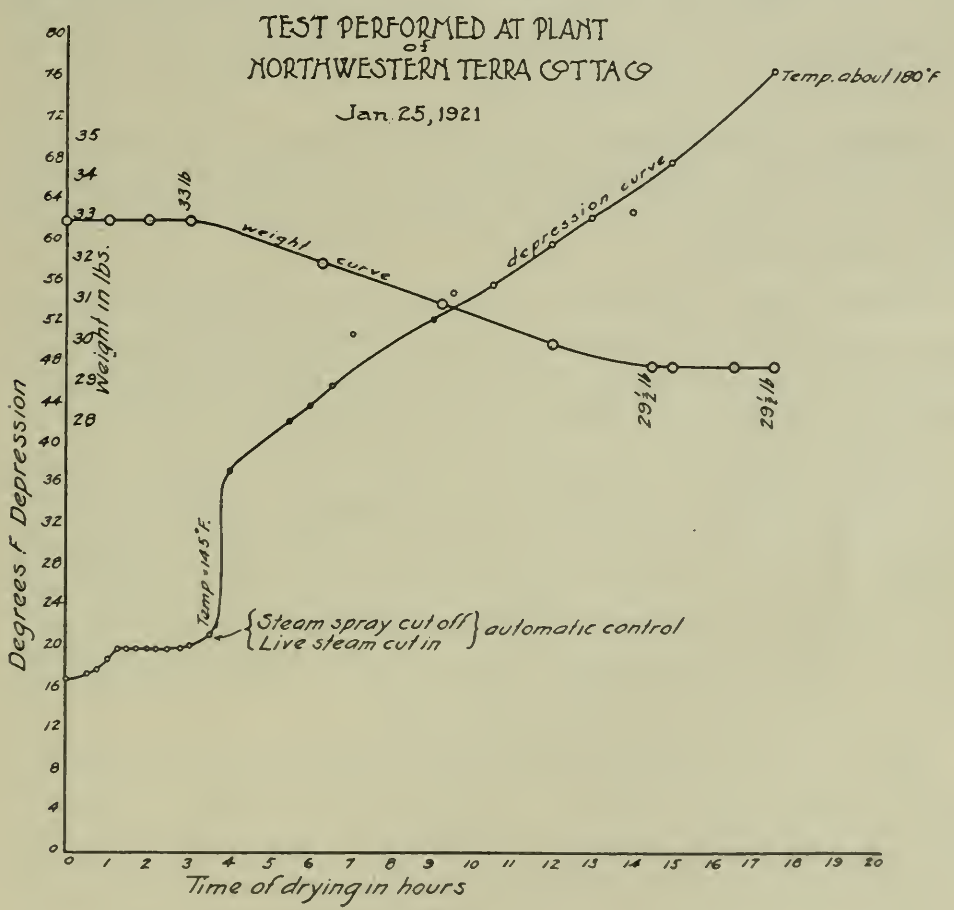


FIG. 4.

Results

Several months' operation of the above system has shown in general the following results, in comparison with the former system, where the air was admitted at one end of the box and taken

out at the other and returned to the fan without any temperature or humidity control.

First: Steam Consumption.—From actual test, the steam consumption has been found to be less than 2.4 lbs. of steam for each pound of moisture removed from the material. This refers to the total steam used, that is, including the steam spray at low pressure steam and high pressure steam. This is equivalent to 760 lbs. of steam per hour, or 25.3 boiler H.P. per hour, or 1.27 boiler H.P. per ton of terra cotta per hour. While we have no reliable figures on which to base a comparison with the old method, we are convinced that the steam consumption with the new system is considerably less.

Second: Floor Space.—There is a saving of at least 50% in the floor space required to dry a given amount of terra cotta, due to the more rapid turnover and the less floor space required for green storage.

Third: Time.—Drying is regularly accomplished in 18 hours and frequently in from 14 to 16 hours, as against 36 to 40 hours in the old system. This permits a turnover of the rooms, which makes possible closer adherence to schedules.

Fourth: Labor.—It frequently happened in the old method of drying, due to variation in atmospheric conditions, steam pressure, and lack of both temperature and humidity controlling equipment, that a considerable proportion of the ware would have to be drawn from the box and reloaded, because of incomplete drying. Under the present system, this is entirely eliminated with a considerable saving in labor cost.

Fifth: Quality of Ware.—There has been a decided reduction in the number of cracked and warped pieces. In fact, it may be said that the only cracking or checking which occurs, may invariably be traced to causes other than the drying operation.

In closing, the authors wish to express their indebtedness and appreciation to the Carrier Engineering Corp., for their valuable coöperation and assistance.

Northwestern Terra Cotta Co.,
Chicago, Ill.

VARIATION IN HEAT TREATMENT OF A SILICA BRICK IN THE CROWN OF A TUNNEL KILN[1]

By A. A. Klein and L. S. Ramsdell

ABSTRACT

It is possible through microscopic investigation of a silica brick to ascertain approximately the heat treatment to which it has been subjected. In this way the temperature difference between the inner and outer ends of a silica brick which had seen service in the arch of a Dressler tunnel kiln was estimated to be at least 200°.

That the mineralogical character of silica brick is subject to variation depending upon the heat treatment which the brick has undergone has been indicated by the results of investigators of this type of refractories. Most of these studies have involved the determination of the constituents of bodies which had undergone known or partially known heat treatment. Recently, however, we had occasion to reverse this process, that is, to attempt to judge the heat treatment of a silica brick from a study of its constituents.

Two samples submitted by the Jeffery Dewitt Company were examined. One of these was a wedge shaped brick which had been used in the arch of the Dressler tunnel kiln at the Detroit plant of this concern, and the other a sample of the original "Star Brand" silica brick as received from the Harbison Walker Company.

Original "Star Brand" Brick

Visually this brick resembled a similar brick from the Harbison Walker Refractories Company described by Insley and Klein.[2] It was composed essentially of a yellowish granular ground-mass which showed a slight vitreous luster with smaller areas of a dull white nature which are termed phenocrysts and which represent the original coarse quartz grains. Segregations of ferruginous material in the form of deeply colored spots vary-

[1] Received March 10, 1921.

[2] *B. S. Tech. Paper*, **124**, p. 13 (1919).

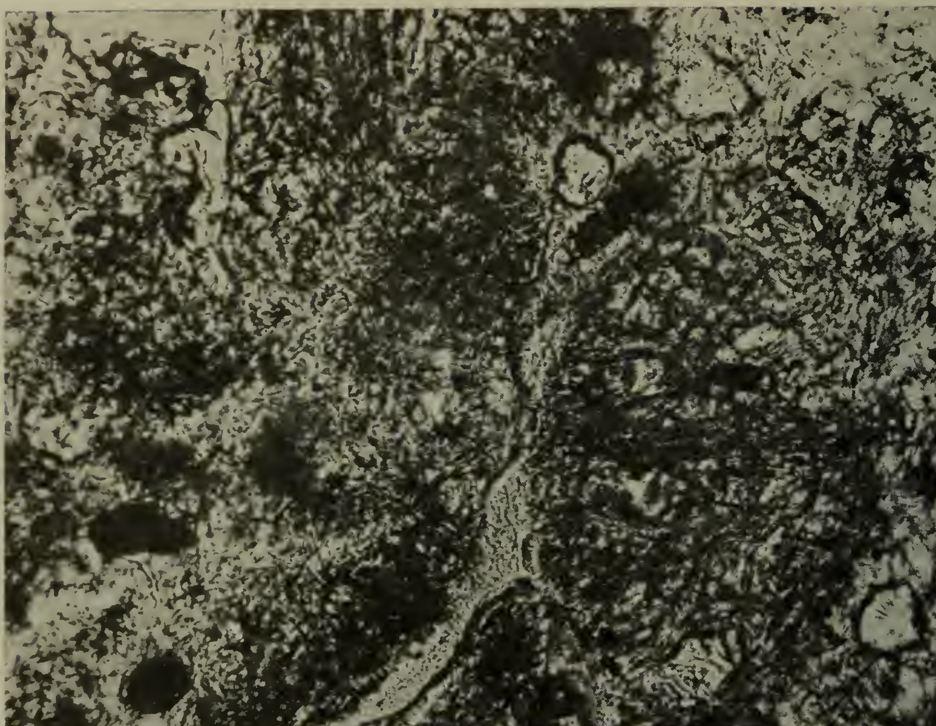


FIG. 1.—"Star" brand brick taken in ordinary light and showing shattered phenocrysts and groundmass. Note the large phenocryst at the right. Magnification—200 diameters.

FIG. 2.—Same as Fig. 1 but taken in plane polarized light with crossed nicols. The light grains consist of uninverted quartz. The black predominant portion of the groundmass is cristobalite and the faint gray crystals in the groundmass are tridymite.

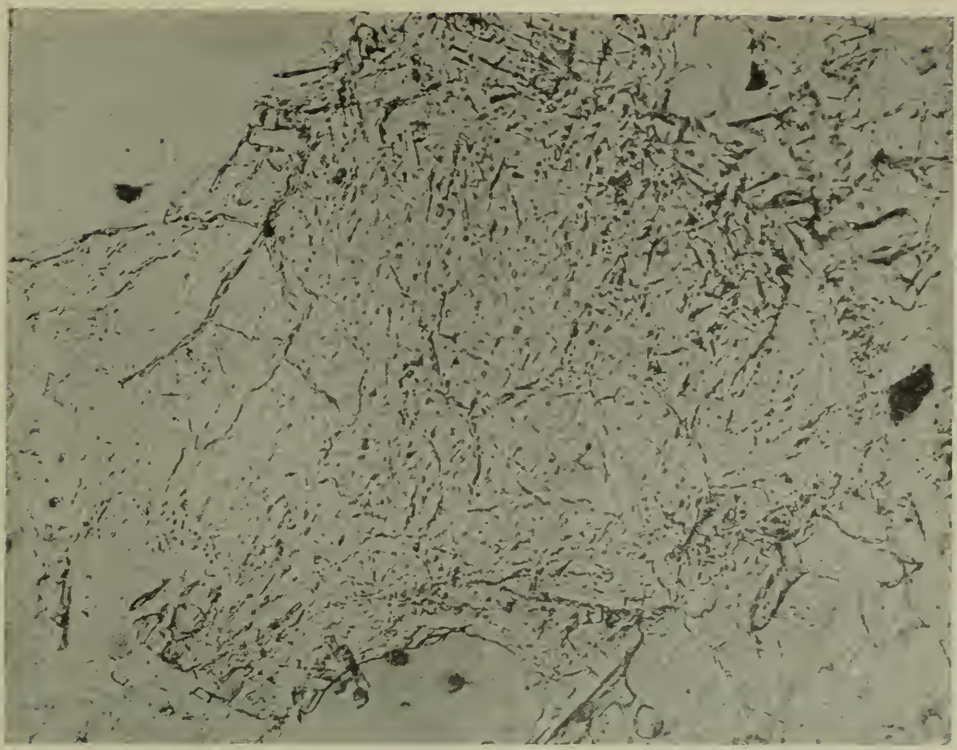


Fig. 3.—Inner end of wedge-shaped brick taken in ordinary light and showing a large phenocryst surrounded by groundmass. Magnification—200 diameters.

Fig. 4.—Same as Fig. 3 but taken in plane polarized light with nicols. Note the small irregular tridymite crystals in the phenocryst and the larger better developed crystals of the same mineral in the groundmass.

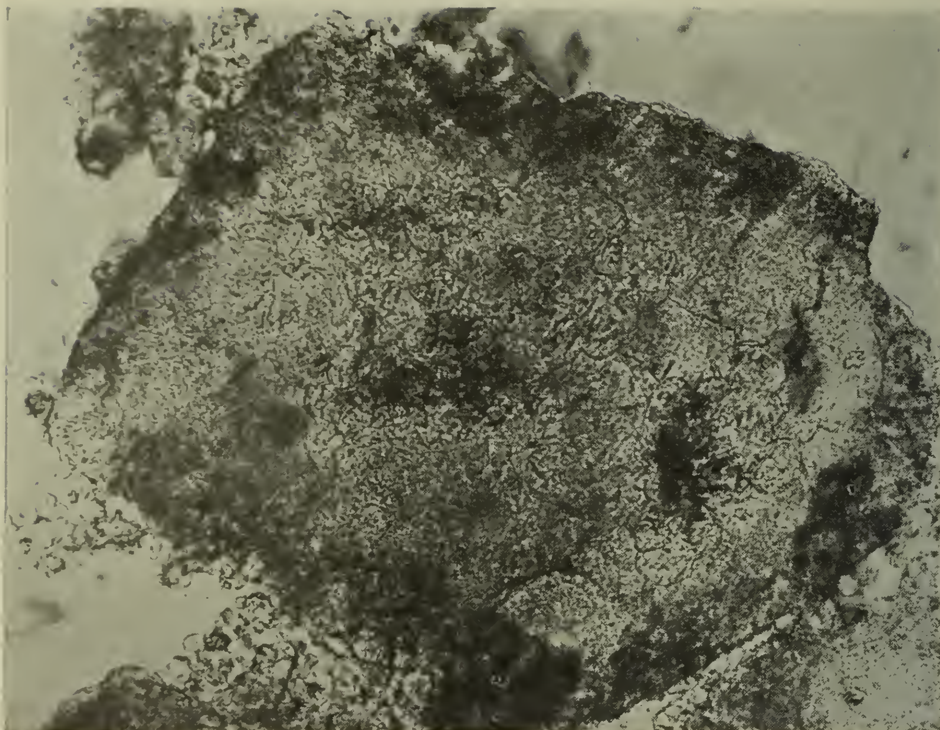


FIG. 5.—Middle zone wedge-shaped brick taken in ordinary light and showing large phenocryst as well as surrounding narrow zone of groundmass. Magnification—200 diameters.

FIG. 6.—Same as figure 5 but taken in plane polarized light with crossed nicols. Note the few grains of residual uninverted quartz as well as the predominant apparently isotropic cristobalite of the phenocryst together with the tridymite crystals of the groundmass.

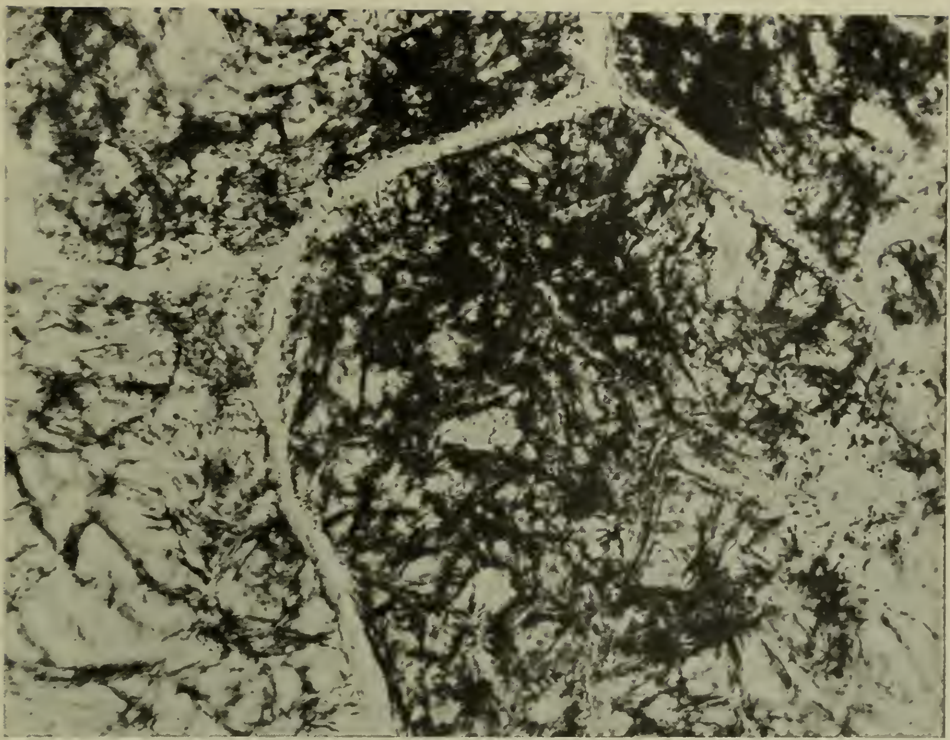


FIG. 7.—Outer end of wedge-shaped brick taken in ordinary light and showing portions of four large shattered phenocrysts together with narrow surrounding zones of groundmass. Magnification—200 diameters.

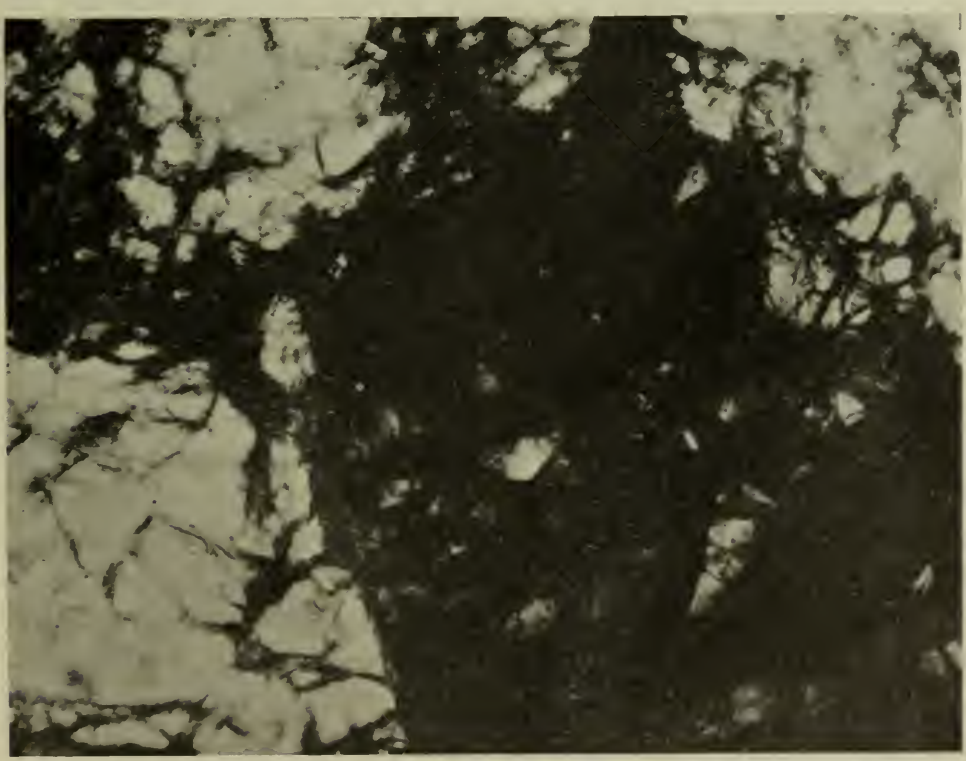


FIG. 8.—Same as Fig. 11 but taken in plane polarized light with crossed nicols. Note that the phenocrysts consist essentially of shattered quartz grains. The largest phenocryst happens to be in almost the position of extinction.

ing from red to black were also found. Microscopically the phenocrysts consisted of shattered quartz containing very little cristobalite. The ground mass consisted essentially of cristobalite and contained a relatively small amount of tridymite with practically no uninverted quartz. The amounts of the various modifications of silica present were as follows: quartz about 25 percent; cristobalite about 55 per cent; tridymite about 20 per cent. These data are essentially the same as those given by Klein and Insley.[1]

Wedge Shaped Brick from Crown of Tunnel Kiln

Three zones of this brick were studies, namely, the larger end (outer), the smaller end (inner) and a zone approximately intermediate between the two and referred to as the middle. Visually the material at the smaller end was deep yellow in color and notably vitreous in luster. The original dull white phenocrysts were also vitreous in luster, and grayish white to yellow in color. Microscopically the composition was found to be tridymite with a relatively small amount of cristobalite and no unchanged quartz. The ground mass contained practically no cristobalite and the tridymite crystals were relatively coarse, often-times showing the characteristic lath shaped crystals and wedge shaped twins. The tridymite of the phenocrysts could be distinguished from that of the ground mass in that the crystals were smaller and did not show the tendency toward the development of their own crystal outlines. These data resemble those given by Insley and Klein[2] for a brick which had been used in a magnesite kiln for 10 or more heats.

Visually the product from the middle zone was light yellow in color and somewhat less vitreous than the material from the smaller end. The amount of the dull white phenocrysts was also smaller. The constituents of the ground mass were tridymite and cristobalite in order of importance. The smaller phenocrysts consisted mainly of cristobalite with very little tridymite and no quartz. The large phenocrysts, however, contained a small residuum of uninverted quartz.[3]

[1] *L. c.*, Figs. 1 and 2.

[2] *L. c.*, Figs. 3 and 4.

[3] Insley and Klein, *l. c.*, Figs. 5 and 6.

The product from the large end resembled the original "Star Brand" brick, visually as well as microscopically. The large phenocrysts consisted of shattered quartz grains showing some inversion to cristobalite. The ground mass consisted essentially of cristobalite with a very small amount of tridymite.[1]

Discussion of Data

It is quite evident that the original "Star Brand" brick received a heat treatment comparable to the best American manufacturing practice. It is also very evident that there was considerable variation in the heat treatment experienced by the wedge shaped brick during its service in the crown of the tunnel kiln. The data indicate that there was a successive decrease in temperature from the small inner end to the large outer end of the brick and that the actual temperature difference was relatively great.

In view of the incomplete data concerning the effect of time and temperature on the constituents of silica brick it is impossible to translate the data into terms of temperature with absolute accuracy but a fair approximation may be arrived at.

For instance the fact that there was no further inversion of the quartz at the large end of the brick indicates that the temperature here could not have been higher than 1250°C since as shown by Insley and Klein,[2] the inversion of quartz in a cube made from a standard silica brick mix did not commence until a temperature of 1250° had been reached.

The fact that the inversion had gone practically to completion with tridymite as the stable modification at the inner side coupled with the fact that the tridymite crystals were on the whole well developed would indicate that the heat treatment here was close to, though somewhat under, the inversion point between tridymite and cristobalite, namely, 1470°. A temperature difference of at least 200°—and possibly more, is therefore indicated.

It is of further interest to point out that notwithstanding its unequal heat treatment the wedge shaped brick showed no cracking or other distinct evidence of weakening.

[1] Insley and Klein, *l. c.*, Figs. 7 and 8.

[2] *L. c.*, p. 22.

SEDIMENTATION AS A MEANS OF CLASSIFYING EXTREMELY FINE CLAY PARTICLES[1]

By H. G. Schurecht

ABSTRACT

A method is described for determining the rate of sedimentation of clays by measuring the suspended weights of a glass plummet suspended in a clay slip at different intervals of time. The specific gravity of the slip remaining in suspension may be calculated as follows: $S = \frac{P_d - P_s}{P_d - P_w}$ where S is specific gravity of slip, P_d is dry weight of a plummet in grams, P_w is suspended weights of plummet in distilled water and P_s is suspended weight of plummet in clay slip. The average weight of clay per cc. is calculated as follows: $C_w = \frac{D(S-d)}{D-d}$, where C_w is average weight of clay per cc., D is the specific gravity of clip and d is the specific gravity of water.

It is impractical to separate by elutriation, clay particles smaller than 0.003 mm. which constitute 50–100% of many clays.

It is possible to classify particles as small as 0.0001 mm. by the plummet sedimentation method and the results are more uniform than those obtained by elutriation.

Introduction

In studying the fineness of grains of clays by the elutriation method[2] it was found that over one-half of the clays tested, contained 50–100 per cent clay finer than 0.003 mm. It is impractical to separate particles smaller than this by elutriation, since it would require several weeks of careful attention and the results obtained would be unreliable because the errors due to currents and temperature variations would be too great.

These facts have been recognized by Schloesing,[3] Sven Odén[4]

[1] Received March 11, 1921. Published by permission of the Director, U. S. Bureau of Mines.

[2] "Elutriation Tests on American Kaolins," This Journal, **3**, 355–378 (1920).

[3] T. Schloesing, *Compt. rend.*, **136**, 1608; **137**, 369 (1904).

[4] Sven Odén. *Internat. Mitt. für Bodenkunde*, **5**, 257–311 (1915); *Bull. Geol. Inst. Univ. Upsala*, **16**, 15 (1919).

and Wiegner[1] who use the sedimentation method for classifying the extremely fine soil particles in preference to the elutriation method. The separation is based upon the fact that fine particles settle slower in water than coarser particles of the same specific gravity. This is shown in Stoke's law which is as follows:

$$V = \frac{2}{9}\frac{D-d}{\eta}gr^2 \text{ or}$$

$$V = Cr^2 \text{ in which } C = \frac{2(D-d)g}{9\eta}$$

V = Velocity of particles in cm. per sec.
η = Viscosity of the liquid.
r = Radius of particles in cm.
g = 981
d = Specific gravity of liquid.
D = Specific gravity of particles.

If a weight (P) of particles of the same size settle in a space (h) the quantity (q) deposited in the time (t) may be calculated as follows:[2]

$$Q = \frac{Pvt}{h} = \frac{PCr^2t}{h}$$

In Stoke's law it is assumed (1) that the particles (molecules) of the liquid are small in comparison with the sinking particles; (2) that the liquid is of infinite extent in comparison with the sinking particles; (3) that the particles are rigid and smooth; (4) that no slipping takes place between the particles and liquid and (5) that the velocity is small or that the radius of particles is not too large. The critical radius for quartz is about 85 μ (= .085 mm.).

C. W. Oseen[3] found that Stoke's law did not apply to particles having a high velocity and derived the following formula which applies to particles having a greater velocity as well as those having a slow velocity:

$$w = 6\,\pi\, r\, \eta\, v\, (1 + \frac{3}{8}\, \frac{dr}{\eta}\, v)$$

w = resistance of the liquid.
v = absolute amount of velocity.

[1] G. Wiegner. "Über eine neue Methode der Schlammanalyse, Die landwirtschaftlichen Versuchs Stationen," 91, 41–79 (1918).

[2] Wiegner, G., *loc. cit.*

[3] Sven Odén, *loc. cit.*

Previous Work

The apparatus used by Sven Odén in studying the sedimentation of soils consists of three parts, a glass cylinder, automatic balance and a recording apparatus. A movable plate is suspended by means of gold threads from the balance and hangs directly over the bottom of cylinder. By the settling of particles from a suspension of soil on the plate, the rate of sedimentation may be obtained by weighing the same at intervals.

For success with this apparatus, Sven Odén states that the following precautions are necessary:

"(1) The plate shall be as near as possible to the actual bottom so that no large space as regards particles shall arise under the plate; (2) the plate shall be at an approximately constant distance from the surface; (3) no clay shall collect between the plate, the wall and the real bottom of the vessel and impair the freely suspending condition of the plate and (4) convection currents within the cylinder of liquid should be prevented as much as possible."

Wiegner's apparatus consists of two glass cylinders, one wide for holding the soil suspension and another narrow, to measure the amount of clay in suspension. These cylinders are joined together, 20 cm. from the bottom of the large cylinder by means of a glass tube containing a stop cock. The large vessel is 1m. high and 3.47 cm. in diameter. The narrow cylinder is 1 cm. in diameter.

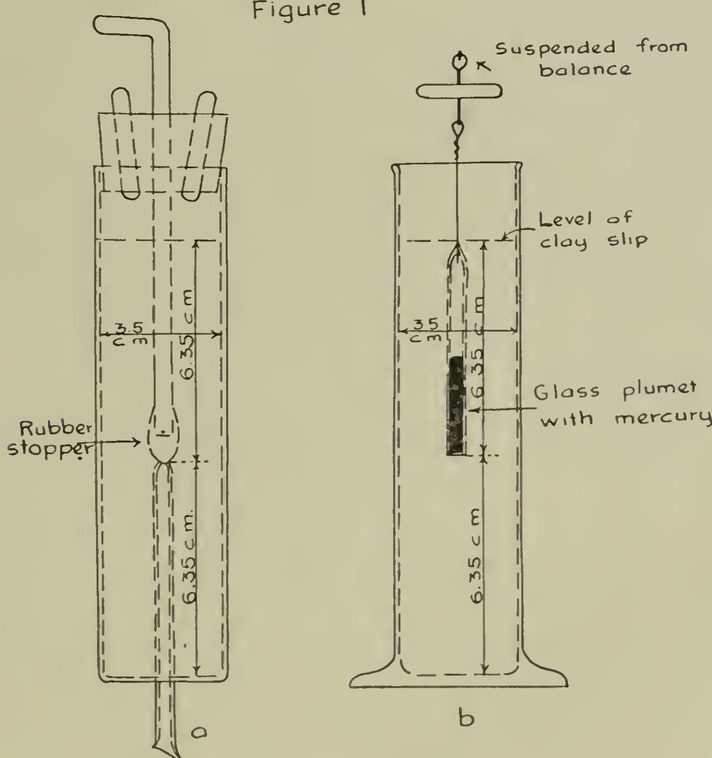
To operate, the stop cock between the two cylinders is closed, the large vessel is filled with a soil suspension and the small tube is filled with distilled water. After thorough shaking, the stop cock is opened and the meniscus in the small tube is forced up above that in the large vessel, due to differences in the specific gravities of the suspension and water. By measuring these differences the specific gravities of the suspension may be calculated at different intervals.

Although this apparatus is satisfactory for testing coarse grained soils for short periods of time, it would seem that when employed for testing fine grained clays for long periods of time, the fine particles sifting through the stop cock would cause considerable error, since it is assumed that the specific gravity of the liquid in the measuring tube is equal to that of water.

Description of Method Used

To overcome many of the objections to the above methods, the Bureau of Mines designed the apparatus shown in figure 1*b*. That shown in figure 1*a* was used to determine quantitatively the clay remaining in suspension at different intervals of time and subsequently to measure the size of grain of the particles thus removed. A comparison was thereby obtained between size of grain observed and that calculated. Also a comparison of decantation with the plummet methods (see Fig. 1*b*) was obtained.

Figure 1



Apparatus for testing the sedimentation of clays

The decantation apparatus shown in figure 1*a* consists of a cylinder containing a drain tube with an opening 6.35 cm. ($2^1/_2$ inches) above the bottom of the vessel. By means of this tube, the liquid with most of the clay particles in suspension may be decanted, although, as is explained later, many particles, on account of the

momentum obtained while settling during decantation, fall below the opening of the drain tube and therefore are not removed by decantation. To determine the amount of clay remaining in suspension at the end of 2 days, the slip is thoroughly shaken, allowed to stand for 2 days and then the suspension above the drain tube is decanted by removing the stopper from the tube. The maximum sized particles thus decanted are those which settle 6.35 cm. in 2 days. Many of the particles, therefore, have settled below the overflow tube and can only be removed by repeatedly adding distilled water, shaking and decanting at the end of two days. This decantation is carried on until all particles remaining in suspension at the end of 2 days are removed. Decantations are also made at shorter intervals of 1 day, 7½ hours, 3 hours, 1 hour, 30 minutes, 15 minutes, 10 minutes and 5 minutes.

In figure 1*b* is shown the apparatus used for measuring the sedimentation by the plummet method. This consists of a glass cylinder 15.5 cm. high and having a diameter of 3.5 cm. A slip containing 1 part clay and 5 parts water is used for the tests. Sufficient NaOH is added to produce maximum deflocculation and the slip is shaken for 8 hours previous to the test.

The plummet consists of a closed glass tube half filled with mercury, this is sealed to a thin copper or gold thread with which it is suspended from a chemical balance. Owing to the fact that the suspended weight is greater with a low clay content than with a high clay content, the variations in specific gravities of the upper half of the slip may be calculated from the suspended weights of the plummet. The plummet method of determining the specific gravities of slips is accurate to 0.0001 g./cc.

To operate, the cylinder is filled to a level equal to 12.70 cm. above the bottom when plummet is in place. It is then thoroughly shaken and placed underneath a balance. The plummet is slowly lowered into the slip, weighed, and record made of the time when the test started and when weights are taken. The weighings are repeated at the following intervals: 1, 2, 3, 5, 10, 20, 35 and 60 minutes; 2, 3, 5 and 7 hours and 1, 2, 3, 5, 10, 15, 20 and 30 days. For many clays, weighing after 5 days is unnecessary since practically all of the clay has settled although some of the finer clays will remain in suspension after 30 days.

After the first 7 hours, the plummet is removed from the cylinder containing the clay suspension and the cylinder is closed tightly with bber stopper. To maintain uniform temperature, the cylinder may be stored in a well insulated box. For the next weighing, the plummet is slowly immersed in the suspension and the suspended weight is taken. The plummet is again removed and the cylinder stoppered until the next weighing. By this method a large number of samples may be tested with one balance and one plummet. This test may be made automatically by using an automatic balance.

On account of the fact that different clays have different specific gravities and different shaped grains, the size of the grain of the particles remaining in suspension will vary with different clays. The size of grain of the particles remaining suspended after different intervals may be determined by carefully removing the plummet and catching a drop of the adhering slip on a microscope slide for examination, being careful not to remove too much slip.

Having determined the suspended weights at different intervals of time, the amount of clay remaining in suspension may be obtained quickly by means of charts as follows:

$$S = \frac{P_d - P_s}{P_d - P_w} = \frac{\text{Wt. of slip equal to volume of plummet.}}{\text{Wt. of water equal to volume of plummet.}}$$

S = Specific gravity of the slip.
P_d = Dry weight of plummet in grams.
P_w = Suspended weight of plummet in distilled water in grams.
P_s = Suspended weight of plummet in slip in grams.

Since $P_d - P_w$ is constant for each plummet, the values of S for different values of $(P_d - P_s)$ may be plotted on a chart as a straight line. With this chart the values of S may be readily obtained from $P_d - P_s$.

The average weight of clay per cc. is then obtained from the following formula:

$$C_w = \frac{D(S-d)}{D-d}$$

C_w = Average weight of clay per cc. of slip.
D = Specific gravity of clay.
d = Specific gravity of water.
S = Specific gravity of clay slip.

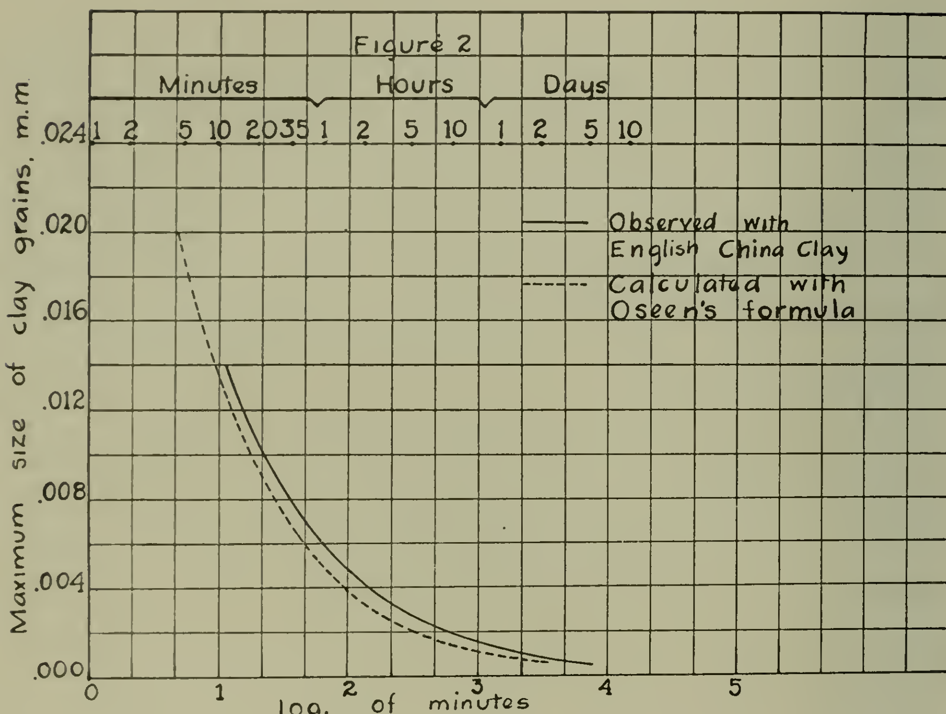


Figure 2
Minutes
Hours
Days
1 2 5 10 20 35 1 2 5 10 1 2 5 10
Observed with English China Clay
Calculated with Oseen's formula
Maximum size of clay grains, m.m.
.024
.020
.016
.012
.008
.004
.000
0
1
2
3
4
5
log. of minutes

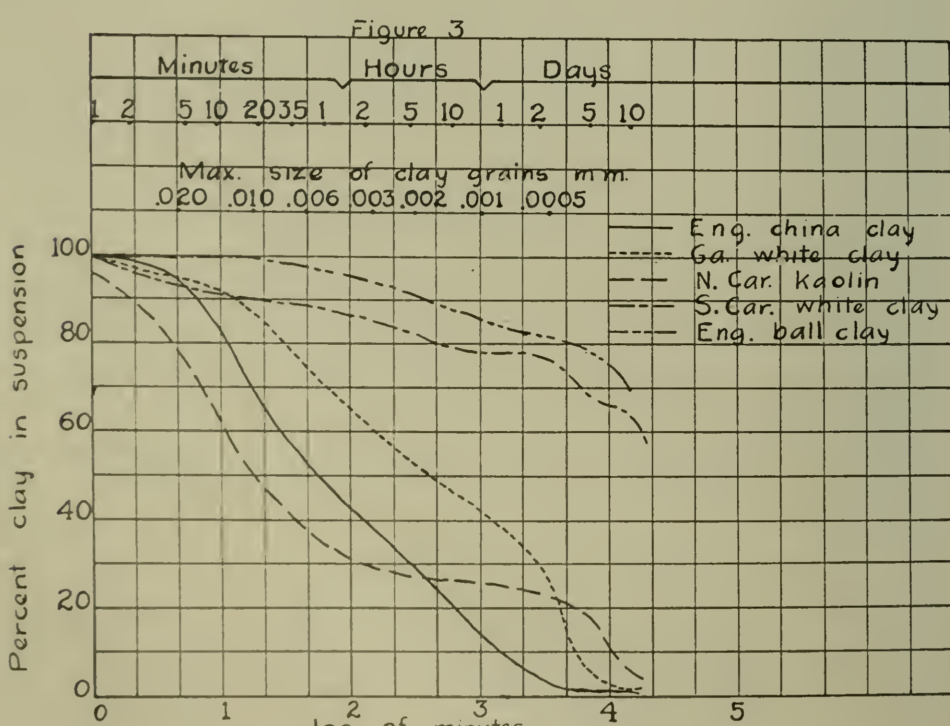


Figure 3
Minutes
Hours
Days
1 2 5 10 20 35 1 2 5 10 1 2 5 10
Max. size of clay grains m.m.
.020 .010 .006 .003 .002 .001 .0005
Eng. china clay
Ga. white clay
N. Car. kaolin
S. Car. white clay
Eng. ball clay
Percent clay in suspension
100
80
60
40
20
0
0
1
2
3
4
5
log. of minutes

Assuming that $d = 1$ for water, the following formula is obtained:

$$C_w = \frac{D(S-1)}{D-1}$$

Since D is constant for a given clay, the values for C_w for different values of S may be plotted on a chart as a straight line. With this chart the values of C_w may readily be obtained. It is advisable to determine the specific gravity of each clay tested since these vary between 2.5–2.7.

Results

The results of the decantation tests are shown in table 1 and figure 2. In table 1 are shown the percentages of clay removed by decantation at different intervals.

In figure 2 are shown the maximum sizes of clay grain of English china clay in suspension for different intervals of time. In both figures 2 and 3, the logarithm of the time in minutes is plotted for convenience in order to shorten the curve. These are slightly higher than those calculated according to Oseen's formula, probably due to the fact that English china clay grains are flat and for this reason their observed diameters, as determined by a micrometer eye piece, would appear larger than the average diameter.

Table I.—Results of Decantation Tests on Clays

No. times	2 days	1 day	7½ hrs.	3 hrs.	1 hr.	30 min.	15 min.	10 min.
1	.570	.465	.550	.585	.675	.575	.600	.300
2	.510	.375	.490	.500	.590	.500	.500	.260
3	.450	.290	.425	.355	.525	.430	.380	.230
4	.390	.210	.355	.285	.450	.375	.325	.200
5	.340	.160	.300	.240	.385	.325	.260	.175
6	.290	.130	.245	.200	.335	.290	.215	.155
7	.245	.115	.200	.160	.285	.250	.175	.140
8	.200	.110	.165	.135	.240	.215	.145	.120
9	.150	.090	.130	.115	.200	.190	.130	.110
10	.100	.080	.100	.095	.165	.160	.120	.100
11	.050	.070	.080	.080	.150	.140	.105	.090
12		.060	.070	.065	.135	.120	.100	.075
13		.055	.065	.060	.115	.110	.095	.065
14		.050	.060	.060	.095	.100	.085	.050
15		.050	.060	.060	.090	.100	.050	.085
Total	3.30	2.32	3.295	3.09	4.635	3.88	3.325	2.125
Per cent	9.34	6.55	9.30	8.74	13.10	11.00	9.40	5.96

TABLE II.—A COMPARISON OF RESULTS OBTAINED BY THE PLUMMET AND DECANTATION METHODS

Time	Plummet Method Specific gravity of silp	 Av. clay content in suspension, grs. per cc.	Decantation Method. Av. clay content as removed by decantation., grs. per cc.
10 min.	1.083	.1320	.0575
15 min.	1.075	.1210	.0535
30 min.	1.061	.0980	.0455
1 hr.	1.047	.0695	.0380
3 hrs.	1.036	.0555	.0282
7½ hrs.	1.025	.0390	.0211
1 day	1.015	.0250	.0137
2 days	1.0033	.0075	.0077

In table 2 are shown the results obtained by the plummet and the decantation methods. With the exception of the clay remaining in suspension at the end of two days the results obtained by decantation are much lower than those obtained by the plummet method. This may be due to (1) the washing away of electrolytes by repeated decantations; (2) particles dropping below the drain tube while the slip is being drained due to the momentum in settling; (3) the fact that the area of the opening in the drain tube is very small in comparison with that of the diameter of the cylinder and (4) the removal of the fine clay in decantation, which reduces the resistance to the settling particles in subsequent decantations, thus causing the particles to fall at a higher speed.

In figure 3 are shown the results of the sedimentation tests made by the plummet method. It is obvious that comparable results may be obtained by this method. For example, by following the dotted line through 0.010 mm., we find that English ball clay has the highest per cent of clay substance (*i. e.*, $<.010$ mm.). The other clays follow in the following order: South Carolina clay, Georgia white clay, English china clay and North Carolina kaolin. In examining the curve representing the material in suspension after 10 days, it is seen that North Carolina kaolin has more material in suspension than the English china clay.

The advantages of the plummet sedimentation method as compared with the elutriation method for classifying extremely fine clay particles are as follows:

1. It permits a separation of the extremely fine clay particles (below 0.003 mm.) which constitute the bulk of many clays. It is impractical to separate particles smaller than 0.003 mm. by elutriation and the elutriation test therefore classifies only the coarse material.

2. It is much easier to maintain a uniform temperature in the sedimentation method since the volume of water is comparatively small and the apparatus may easily be stored in well insulated receptacles. In large elutriation cans, convection currents result from one wall of the laboratory being colder than the other, causing considerable error.

3. In the elutriation method it is very difficult to maintain maximum deflocculation throughout the test since the added electrolyte is continually being washed away. In the sedimentation (plummet) method, the electrolyte content remains constant throughout the test.

4. The sedimentation test is much more rapid. Ten tests may be made by this method in the time necessary to make one by the elutriation method.

Ceramic Experimental Station,
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THE APPLICATION OF HEAT IN CERAMICS

By Gerald Fitz-Gerald

ABSTRACT

After discussing the relation of draft to heat transfer and kiln dimensions the conclusion is reached that the higher the flame temperature in the kiln the more economical will be the firing operation, and that a combination of natural and mechanical draft makes an ideal installation.

Scope of the Paper.—In a discussion, published in the November, 1920 issue of the Journal, the comparative merits of artificial and of natural draft were briefly considered. It is the purpose of the present paper to take up the application of artificial draft with gaseous or liquid fuels. The same conditions hold good for solid fuels, but the work considered in this paper was done with fluid fuels only. Some of the theory of the draft and its relation to the heat application will be first taken up and the paper will close with some data on the results obtained.

Equipment Used.—The material for this paper was obtained by observation on a down draft kiln of rectangular construction fired with both natural and artificial draft and with both liquid and solid fuels.

The natural draft equipment for gas consisted of the common type of atmospheric burner, used on kilns wherever natural gas is available. The artificial draft equipment for both gas and oil consisted of a motor-driven low pressure air blower, which supplied the air for combustion for both gas and oil and, when burning gas, mixed the gas and air together before delivering the resultant mixture to the kiln.

Character of Heat.—Heat is evolved as the result of the combination of the fuel with the oxygen of the air. It is impossible however, to consider the heat entirely apart from the material that contains it, that is, the products of combustion. In order to consider these in detail, we must first consider the appearance of a flame, preferably a gas flame, as it is more easily studied than is an oil or coal flame.

When the flame is confined within a kiln, its appearance is, in general, characteristic of its properties. Thus the yellow flame of current practice is a reducing flame. When, however, the kiln gets so hot that the flame disappears altogether, we are left in doubt as to whether or not the flame is reducing, neutral or oxidizing. In ceramic work in general, a slightly oxidizing atmosphere is to be preferred. Sometimes however, it is necessary, more especially towards the end of the burn, to change from an oxidizing atmosphere to a reducing atmosphere in order that combustion may take place in all parts of the kiln and bring them up to the same temperature. This brings us to a consideration of the character of the products of combustion and their movement within the kiln from a physical standpoint.

Heat Travel.—In order to make the matter as clear as possible, I have likened the flow of gases through the kiln to that of a stream of water. Starting at a high temperature and at some degree of pressure, the gases flow through the kiln, losing both pressure and temperature as they go. This stream of gases has a certain volume which it is interesting to estimate however roughly. It is known that one cubic foot of natural gas requires for complete combustion approximately ten cubic feet of air, which gives eleven cubic feet of mixture. On ignition the eleven cubic feet expand quite suddenly to about sixty cubic feet. It is therefore plain that if the kiln is burning 1000 cubic feet of natural gas per hour, we have a stream flowing through the kiln, the volume of which is 60,000 cubic ft. per hour.

Consider a kiln about 10 feet square. This kiln has an area of 100 square feet. The speed of the gases through this kiln will be the volume divided by the area, which gives us ten feet per minute. As the kiln is 10 feet long the gas remains within it for one minute only. If, however, the kiln were 5×5 instead of 10×10, the gases would remain in it only 15 seconds or, in other words, the kiln would have to be 40 feet long for the gases to remain one minute.

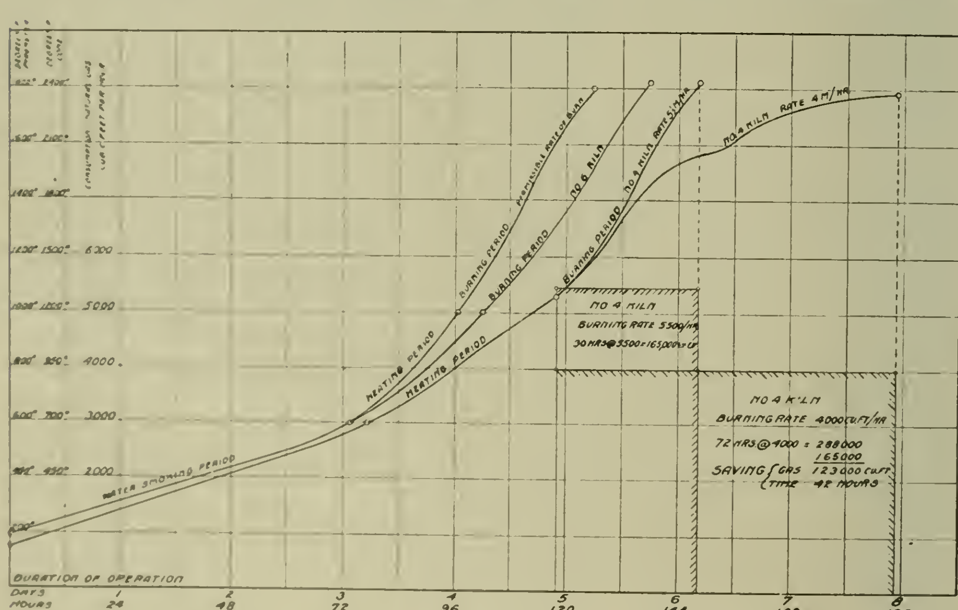
The theoretical flame temperature of the fuels in question is between 4000 and 5000 degrees F. This temperature is reduced by expansion and by deferred combustion, but 2500–3000 degrees F can be attained without trouble. It should be remembered that a high initial temperature is favorable to heat transmission

For a given kiln the speed of travel of the gases is constant for a given rate of consumption. It is therefore evident that other things being equal, the higher the initial temperature of the gases, the more economical will be the absorption of heat by the ware.

In order to attain this high initial temperature, the burner equipment should be of ample size. It should also bring together as intimately as possible the fuel and the air required for combustion. With gas fuel this is generally attained by mixing the gas and the air together before they leave the nozzle of the burner. With oil fuel this is attained by atomizing the oil into as fine a spray as possible, and supplying all the air necessary for combustion through the nozzle, with the spray.

Transfer of Heat.—I have likened the flow of gas through the kiln to that of a stream or river. A more exact comparison is that of a Pelton wheel, or over-shot wheel, located on a mountain stream.

In the water power installation we have the reservoir; the



flume; the intakes, or stand pipes; the nozzle in which the potential energy of the water head is transformed into kinetic energy; and the wheel that absorbs the energy from the water in a very brief space of time lasting hardly more than one or two seconds.

In the kiln installation we have the fuel pipes leading the fuel and the necessary air up to the burner in which the fuel is brought

into close and intimate contact with the air; the nozzle directing the stream of mixture; the fire box in which the potential chemical energy of the fuel is transformed into the thermal energy of the products of combustion and finally the ware in the kiln absorbs the energy of the products of combustion, as the Pelton wheel in its housing absorbs the energy of the water.

The curve of operation is practically the same in each case. The power curve, of course, will vary, as more or less energy is absorbed. So will the heat curve of the burnt gases vary from the lighting up of the kiln until its shutting down. At first the absorption will be pretty rapid as the differences in temperature between the ware and the gases is great but the curve will gradually flatten out as the temperature of the ware increases and as the temperature head decreases.

A complete study of the temperature curve of the burnt gases would include the action of the recuperators if these are used. A recuperator may be likened to the suction pipe from the turbine in that it seeks to absorb as much energy as possible after the gases have left the kiln and after the water has left the turbine.

Conclusions

It is evident that the successful application of heat to the ware in the kiln depends on the means adapted to make the application.

Natural Draft.—Natural draft is generally adopted as it is always available and is free from mechanical breakdown. It can be very efficient if the complete installation is well designed, which unfortunately is seldom the case and so in most cases natural draft does not get a fair show.

Mechanical Draft.—Mechanical draft when installed is always designed for the case in hand and consequently is in most cases more efficient than natural draft. While subject to mechanical breakdown, it is not subject to loss of efficiency due to atmospheric disturbances.

Combination Natural and Mechanical Draft.—A combination of natural and mechanical draft is a happy solution of the problem. The mechanical apparatus is generally applied to overcome the deficiencies of the natural draft system already existing. This is quite frequently the case in solid fuel-burning in-

stallations. In the case of fluid fuel, either gas or oil, the apparatus also serves another purpose—that of bringing the fuel and the air required into intimate contact.

Capacity.—Other conditions being equal, the apparatus having the greatest capacity is apt to prove the most economical. This sounds like a paradox, but is only another way of repeating our former conclusion of the range of operation. A practical illustration will serve to conclude this paper.

Economy.—Take a material or ware to be burnt at 2000°F Consider two sizes of the same apparatus, whether for natural or mechanical draft, one capable of maintaining 2500°F in the kiln, the other 3000°F in the kiln. Of the two the second unit is probably the most economical, for the reason that its temperature head of 1000°F is just twice as high as the head of the other (500°F), and can be maintained with less than twice the fuel consumption. On many kilns an increase in the rate of combustion of twenty five to fifty per cent, gives a fuel economy and a time saving of twenty-five per cent each.

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THE PRODUCTION OF SOME WHITE ENAMELS FOR COPPER[1]

By R. R. Danielson and H. P. Reinecker

ABSTRACT

The investigation deals with the development of some white enamels for copper watch dials, thermometer scale plates, and signs. The effect of varying Na_2O, PbO, cryolite, SiO_2 and B_2O_3 on the properties of the enamels was studied in twenty enamel compositions. The following conclusions were reached: (1) Correct melting is extremely important in the preparation of copper enamels; (*a*) Slow air cooling of the frit is preferable to quenching in water. (*b*) Repeated melting tends to promote opacity and to eliminate dissolved gases. (2) A somewhat reducing atmosphere during firing avoids oxidation of the copper. (3) Slight changes in enamel composition have a decided effect on the resultant properties. (4) Sodium oxide promotes gloss but reduces opacity very decidedly. (5) Lead oxide promotes fusibility without materially reducing opacity, except by dilution. (6) Cryolite is not a desirable flux or opacifier as it tends to develop a matt finish. (7) It is desirable to keep the boric oxide content low and good enamels may be produced without it. (8) By using "white arsenic" as an opacifier tin oxide is unnecessary. (9) The following were the best enamels obtained and these appear to be equal to a number of watch dial enamels examined: C-19 and C-20. (10) A second group of compositions which appear to promote results equal to those in use for thermometer scales, advertising letters, etc.,are C-10, C-21, C-22, and C-24. In selecting these compositions, all factors such as opacity, gloss, texture, fit and resistance to attack of copper have been considered.

Batch Compositions of Best Enamels—(To give 100 parts melted)

	Quartz	Feldspar	White lead	Red lead	Potass. nitrate	Soda ash	Oxide arsenic	Potass. carbonate	Cryolite	Sodium nitrate	Tin oxide	Borax
C-19	34.8	1.3	62.0	....	3.2	1.9	5.2	2.3	...	2.7	..	...
C-20	32.8	1.3	64.2	....	3.2	1.9	5.2	2.3	...	2.7	..	...
C-10	30.0	...	58.0	....	2.4	4.3	5.5	5.0	7.5	...	..	...
C-21	30.8	1.3	66.5	....	3.2	1.9	5.2	2.3	...	2.7	..	...
C-22	31.0	...	....	48.3	3.2	2.3	5.5	...	...	4.1	10	4.1
C-24	31.0	...	....	49.8	3.2	3.4	5.5	...	...	4.1	10	...

[1] Received June 16, 1921. By permission of the Director, Bureau of Standards.

The literature of the American Ceramic Society is decidedly lacking in information regarding the enameling of sheet copper, a business which is taking on considerable importance in line with the development of the other branches of the industry. Only one paper on this subject can be cited, a treatise on art enameling.[1] This work, however deals only with clear glass enamels of the cloisonne type and has not undertaken the development of white enamels of the type used for watch dials, thermometer scales and name plates.

Aside from this reference the few text books on the subject are so vague and lacking in details of technique that they are of little assistance to one attempting the development of enamels for copper.

The Bureau of Standards has had repeated requests for information relating to this type of enamel. It was therefore decided to carry on a limited investigation to develop a few compositions of commercial value and at the same time gather information as to the possible variations in ingredients and the effects on the enamels. In carrying on the work considerable information was obtained regarding the technique of copper enameling which was found in some respects to differ widely from that of sheet steel enameling.

The brief nature of this investigation made impossible the study of a large number of compositions laid out in a systematic fashion but it is believed the general results and conclusions will be of value to those interested in this type of enameling.

Two copper enamels which were reported as having given satisfactory results were considered as a basis for the investigation. The melted compositions of these enamels are as follows:

	A	B
SiO_2	38.0	31.5
PbO	51.4	44.7
CaO	0.4	....
Na_2O	1.5	5.4
K_2O	3.4	1.5
As_2O_3	5.3	5.5
SnO_2	...	9.9
B_2O_3	...	1.6

[1] "Art Enameling on Metal," by J. Minneman, *Trans. Amer. Ceram. Soc.*, **13**, 514 (1912).

Based on the average of these compositions, 20 enamels have been prepared. The batch compositions are given in table 1, and the percentage compositions in tables 2–5.

Preparations of Enamels

The enamels were prepared in the usual manner by weighing 4.5 pound samples, mixing thoroughly by hand and then smelting in crucibles in a gas fired crucible furnace. The time required to melt the batches to a clear molten enamel varied from 30 to 50 minutes, when the enamels were chilled by cooling in water. The frits were then dried and ground dry in porcelain ball mills until they passed an 80-mesh sieve.

It was soon noted, however, that some of the enamels did not have the opacity which might be indicated by their compositions so the smelting was repeated, using a method foreign to that in use in ordinary enameling processes but apparently advocated by makers of copper enamels. Under this latter method, the melted enamels are cooled by casting on an iron slab, then melting is repeated by returning the chilled enamel to the crucible. The process is repeated a number of times, three meltings being accepted in our work. The beneficial results of this remelting were soon apparent for the enamels produced were much more opaque than those chilled in water and it was also noted that there was less tendency for the enamels to blister and develop pinholes.

This phenomenon of increased opacity is undoubtedly due to two factors. Reheating of glasses containing such ingredients as arsenic oxide tends to increase their opacity due to the precipitation of the arsenic in the glass. Further, the remelting tends to produce more opaque enamels in reducing the tendency to "oversmelt." It apparently is much easier to eliminate the gases by subsequent reheatings than it is to drive these off at one initial heating and at the same time retain the necessary ingredients which serve as opacifiers.

Application and Firing of Enamels

The copper plates used in the investigation were 2″ x 3″ in size and of 22 gauge metal. They were prepared by boiling in an al-

TABLE 1.—BATCH COMPOSITIONS OF COPPER ENAMELS

To Give 100 Parts Melted

	Quartz	Feldspar	White lead	Red lead	Potass. nitrate	Soda ash	Oxide arsenic	Potass. carbonate	Whiting	Magn. carbonate	Cryolite	Sodium nitrate	Tin oxide	Borax
C-1	30.0	...	58.0	....	9.6	17.3	5.5	...	...	...	..	...	..	...
C-2	30.0	...	58.0	....	9.6	....	5.5	...	...	...	10	...	..	...
C-3	30.0	...	46.3	....	9.6	17.3	5.5	...	...	...	10	...	..	...
C-4	30.0	...	46.3	....	9.6	....	5.5	...	...	...	20	...	..	...
C-6	30.0	...	58.0	....	9.6	8.6	5.5	...	...	...	5	...	..	...
C-7	36.0	1.3	58.5	....	2.4	2.7	5.4	...	0.4	0.4	..	...	..	...
C-8	34.0	1.3	58.5	....	2.4	6.2	5.4	5.4	0.4	0.4	..	...	..	...
C-9	32.0	1.3	58.5	....	2.4	9.6	5.4	5.4	0.4	0.4	..	...	..	...
C-10	30.0	...	58.0	....	2.4	4.3	5.5	5.0	...	...	7.5	..	..	...
C-12	35.0	1.3	58.5	....	2.4	4.4	5.4	5.4	0.4	0.4	..	...	..	...
C-13	31.0	...	....	46.0	3.2	6.8	5.5	...	...	...	..	4.1	10	...
C-17	32.2	1.1	52.0	....	3.75	1.6	4.6	2.7	...	...	..	2.2	..	...
C-18	31.0	...	59.0	....	2.1	4.3	5.5	5.0	...	...	..	...	..	...
C-19	34.8	1.3	62.0	....	3.2	1.9	5.2	2.3	...	...	..	2.7	..	...
C-20	32.8	1.3	64.2	....	3.2	1.9	5.2	2.3	...	...	..	2.7	..	...
C-21	30.8	1.3	66.5	....	3.2	1.9	5.2	2.3	...	...	..	2.7	..	...
C-22	31.0	...	....	48.3	3.2	2.3	5.5	...	...	...	..	4.1	10	4.1
C-23	31.0	...	....	46.2	3.2	0.8	5.5	...	...	...	..	4.1	10	9.5
C-24	31.0	...	....	49.8	3.2	3.4	5.5	...	...	...	..	4.1	10	...

TABLE 2.—EFFECT OF VARYING FLUXES

Constant Part 80.—30 SiO_2, 40 PbO, 4.5 K_2O, 5.5 As_2O_3

Variable Part 20.—Na_2O, PbO and Cryolite

	Variables				Remarks			
Enamel	Na_2O	Cryolite	PbO	SiO_2	Opacity	Gloss	Texture	Effect on copper
C 1	10.0	..	10	...	Clear glass	Very good	Pin-holed	None
C 6	5.0	5.0	10	...	Poor	Good	Pin-holed	None
C 10	2.5	7.5	10	...	Good	Fair	Pin-holed	None
C 2	....	10.0	10	...	Very good	Poor	Pin-holed	Very slight
C 3	10.0	10.0	..	...	Good	Poor	Fine pin-holed	Slight
C 4	....	20.0	..	...	Good	Matt	Pin-holed	Attacks copper
C 18	2.5	5.5	11	1.0	Good (yellow)	Good	Crazed & wavy	Attacks copper

TABLE 3.—EFFECT OF VARYING SiO_2 AND Na_2O

Constant Part 96.—32 SiO_2, 1.3 Feldspar, 50.5 PbO, 4.8 K_2O, 1.6 Na_2O, 5.4 As_2O_3, 0.22 CaO, 0.18 MgO

Variable Part 4.—Na_2O and SiO_2

	Variables		Remarks				
Enamel	SiO_2	Na_2O	Opacity	Gloss	Fusibility	Texture	Attack on copper
C 7......	4.0	...	Fair	Good	Refractory	Wavy	Slightly attacks
C 12......	3.0	1.0	Poor	Good	Refractory	Wavy	None
C 8......	2.0	2.0	Glass	Good	O.K.	Crazed slightly	None
C 9......	...	4.0	Glass	Good	O.K.	Crazed slightly	None

TABLE 4.—EFFECT OF VARYING SiO_2 AND PbO

Constant Part 94.— 30.8 SiO_2, 1.3 Feldspar, 51.5 PbO, 3.1 K_2O, 2.1 Na_2O 5.2 As_2O_3

Variable Part 6.—PbO and SiO_2

	Variables		Remarks			
Enamel	PbO	SiO_2	Opacity	Gloss	Texture	Attack on Copper
C 17...........	...	6.0	Good	Fair	Wavy	Attacks copper refractory
C 19...........	2.0	4.0	Good	Good	Good	None
C 20...........	4.0	2.0	Good	Good	Good	None
C 21...........	6.0	...	Fair	Good	Good	None

TABLE 5.—EFFECT OF B_2O_3 ON COPPER ENAMELS

Constant Part 96.5.— 31 SiO_2, 45 PbO, 1.5 K_2O, 3.5 Na_2O, 5.5 As_2O_3, 10 SnO_2

Variable Part 3.5.— Na_2O, PbO and B_2O_3

	Variable			Remarks			
Enamel	Na_2O	PbO	B_2O_3	Opacity	Gloss	Texture	Effect on copper
C 13...........	2.0	...	1.5	Poor	Good	O.K.	Attacks copper
C 22...........	...	2.0	1.5	Fair	Good	O.K.	Very slight
C 23...........	...	...	3.5	Good	Good	Chipped	Slight
C 24...........	...	3.5	...	Good	Good	O.K.	None

kaline bath and then given a mild pickling in dilute nitric acid. Following the pickling, the plates were thoroughly rinsed to remove the excess acid and then dried.

The plates were then given a very light wash of the enamels ground in water as it was found that this prevented excessive oxidation of the metal during the firing process. It was also noted that coating the backs of the plates tended to reduce buckling of the copper. The buckling would not have permitted the development of the true adhering quality of the enamel, as a slight tendency of an enamel to chip, due to strain, would have been increased by the buckling of the plate. The back of enameled copper is also usually given a light enamel in commercial practice. A layer of powdered enamel was then sifted over this wash when the plates were ready for firing.

In the preliminary work of this investigation, the samples were fired in a small electric muffle furnace. It was soon found that poor results were obtained, due, it is believed, to the slow radiation of heat from the muffle walls and the highly oxidizing conditions of the furnace atmosphere, both of which tended to excessive oxidation of the copper before the enamel had fused.

A gas fired muffle furnace with a muffle 14″ x 24″ x 18″ was substituted for the electric furnace with a great improvement in the results. Temperatures were determined with a platinum platinum-rhodium thermocouple encased in a thin porcelain protecting tube and suspended directly over the plates.

The time and temperature for firing will vary with gauge of metal, thickness of enamel coating and other local conditions, so it is sufficient to state that the temperature varied from 800°C to 950°C and the time from 45 seconds to $2^1/_4$ minutes.

Discussion of Results

To facilitate a study of the various enamels they have been arranged in four groups, in which by direct and cross comparisons, the variations in fluxes and in the refractory portion (silica and feldspar) can be studied. In table 2 is shown a group of seven enamels, arranged to show the effect of varying fluxes on the resultant enamel. The first four enamels of the group comprise a study of the effect of reducing sodium oxide with a corresponding increase in cryolite. Cryolite is not a usual ingredient of copper enamels and this study tends to explain this omis-

sion. While cryolite increased the opacity, there was a corresponding decrease in gloss such that when it comprised ten parts of the melted batch, the gloss was poor and 20 parts had produced a matt enamel. Increase of cryolite tended to promote attack of the copper and it was noted that lead oxide was also more active in attacking the copper. In comparing C 10 and C 18, the effect of reducing the cryolite two parts and increasing the silica and lead oxide each one part is shown in improved gloss. A point which was evident all through the work was the marked effect of small variations in the composition of this type of enamels, as compared with those for sheet steel and cast iron.

The effect of reduction in the silica content with corresponding increases in sodium oxide is shown in table 3. While the gloss of the enamels was good, the opacity decreased rapidly as sodium oxide was substituted for silica. The higher silica enamels were also exceedingly refractory and the tendency of Enamel C-7 to attack the copper was undoubtedly due to the necessity of subjecting this enamel to a sharp fire to properly fuse it over. This study led to the conclusion that high silica was a detriment to good copper enamels but that replacing silica by soda was not the correct method to reduce refractoriness in view of the tendency of the latter to reduce opacity.

Therefore, a group of four enamels was planned to correct the refractoriness of silica without decreasing opacity. In table 4 is shown the effect of decreasing silica with corresponding replacements by PbO. This change in composition was beneficial from all viewpoints in that refractoriness was reduced and texture and gloss were benefited. There is evident, though, in the largest increase of lead a tendency to loss of opacity. This would be expected beyond a certain limit in that lead is not an opacifier and would simply tend to decrease opacity by dilution.

Since some of the base enamels contained boric oxide, a group, table 5, showing some slight variations in this connection was tried. It was noted that soda and boric oxide in combination tended to promote attack of the copper. While the contents of boric oxide were small, it is not believed that beneficial results will be derived from the use of boric oxide in copper enamels.

Conclusions

While the number of enamels covered in this work has been small, it is believed that the conclusions summarized in the abstract can be derived from the work and that these will be of considerable assistance to those interested in the development of copper enamels.

BUREAU OF STANDARDS,
WASHINGTON, D. C.

AN OXYGEN-ACETYLENE HIGH-TEMPERATURE FURNACE[1]

By Hewitt Wilson

ABSTRACT

A detailed description, with drawing, is given to show the use of oxy-acetylene gas in a small furnace for using refractory cones. The advantages claimed, are (1) simplicity of construction, operation and repair; (2) ease of control; (3) high temperatures obtainable; (4) oxidizing atmosphere; (5) comfortable working conditions, owing to the small volume of hot combustion gases; and (6) portable character of the furnace, fuel and firing apparatus, permitting its use in localities where gas or electricity can not be obtained, such as in the field or at the mine. The following change is suggested in the Ceramic Society's specified rate of heating for cone fusion tests. "The rate of heating shall not exceed that corresponding to one-half a cone (approximately 10 degrees C) per minute within a range of ten cones below that of the final fusion cone and this rate shall preferably be decreased to one cone per five minutes within two cones of the final cone of fusion."

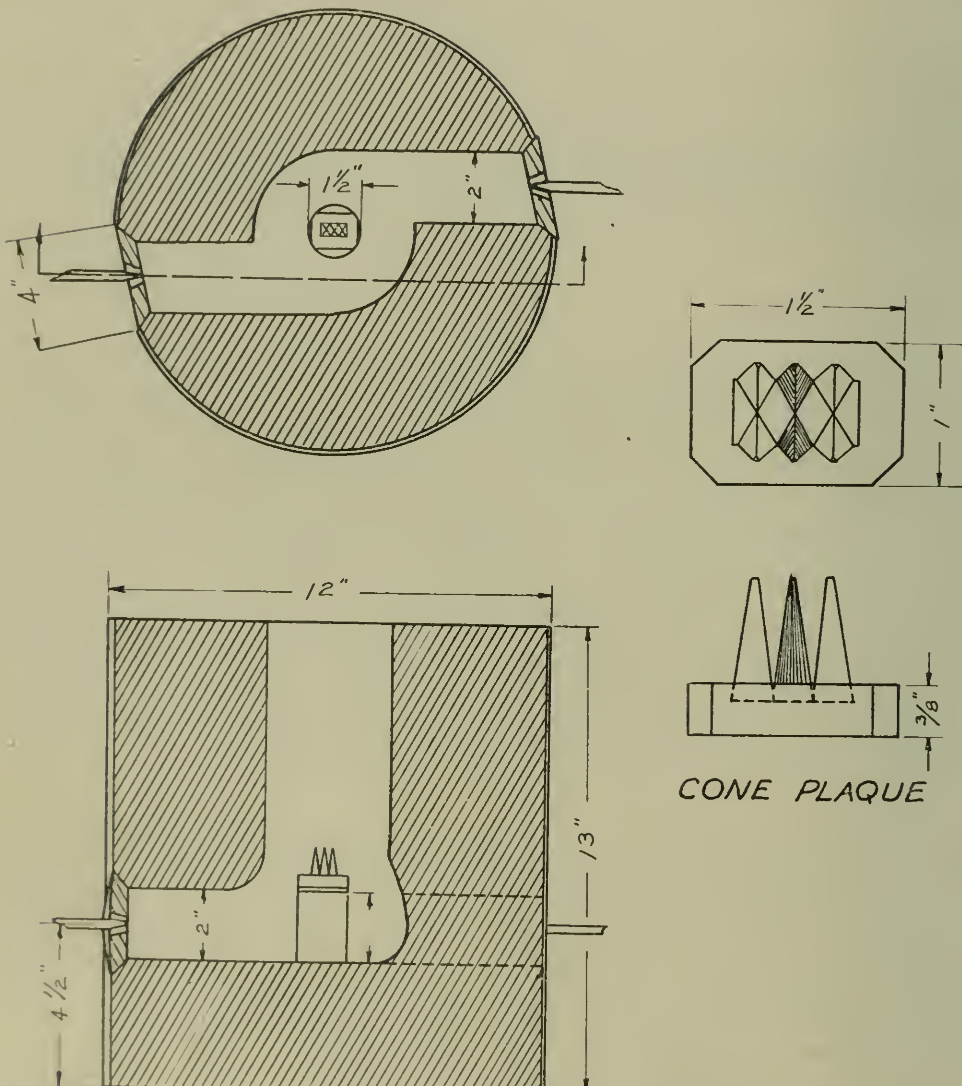
With the recent development of the apparatus and commercial use of the gases, oxygen and acetylene, for rapid welding and cutting of metals, it is natural that these high-temperature flames should be used in the fusion tests of fire clays and other refractories. Washburn and Libman[2] have shown that the oxy-acetylene flame can be used for high temperature ceramic work.

This is not the description of a "paper" furnace but of one which has given good service in the Ceramics laboratory of the College of Mines, University of Washington, in the fusion of over 500 clay samples from the State of Washington, ranging from cone 2 to cone 35.

The furnace shown in the accompanying sketch is similar to the fusion furnaces used where natural gas of high calorific value can be obtained. As the volume of the oxygen-acetylene gas

[1] Received August 6, 1921. By permission of the Director, U. S. Bureau of Mines.

[2] Washburn, Edward W., and Libman, Earl E., This Journal, 3, 634–640 (1920).



OXY-ACETYLENE
CONE FUSION FURNACE

and its products of combustion is small and the temperature of the flame is very high, the size of the furnace is relatively small. The one described can be carried in the arms.

Burners and Flame.—Two small "lead-burning" torches, placed on opposite sides of the furnace, direct the flames

tangentially to the circumference of the circular chamber.[1] The combustion gases follow the usual spiral path around the cone pedestal and out at the top. This center stand is high enough to keep the cones out of the direct blast of the flame. Uniform temperatures can be produced on all sides of the cone plaque by adjusting the burners to supply the proper amounts of oxy-acetylene and by preserving a symmetrical interior design of the fire chamber together with the centering of the cone plaque. A projecting portion of the furnace wall or a fallen particle may so deflect the flame that a local hot spot may be produced.

Lining.—For fire-clay fusion temperatures we have successfully used alundum, magnesia, and an alundum-magnesia mixture. We have had poor results with zirkite (early fusion), pure china clay (early fusion), carborundum (early fusion, accompanied by blistering and bubbling), combinations of clay and magnesia, and a clay-carborundum mixture.

For a magnesia lining, a good grade of brick may be cut and fitted into the circular jacket, or the lining may be made in the following manner. We press a prepared, calcined ferro-magnesia mixture in a mold and fire the resulting shape. This is then backed with fire clay or an insulating material and packed into a suitable container, which may be an empty can of suitable dimensions. We prepare the calcined magnesia by crushing a good grade of magnesia brick to pass a 20-mesh sieve and adding enough gum or dextrine and a small amount of water to make the mass plastic. This can be packed into position for either the original lining or for repairs. It derives its dried strength from the gum, while the fired strength may be obtained directly by heating with the oxy-acetylene flame. One magnesite brick will provide a number of cone plaque stands. After cutting to approximate size with a hammer, the stands can be rounded to dimension on an emery wheel. A thin layer of iron chromate must be daubed on the top of the stand to prevent violent reaction between the clay and magnesia above 1600°C.

Cone Plaques.—We mix raw English china clay with an equal weight of English china clay, calcined to cone 15, and ground to

[1] R. T. Stull: "New Type of Laboratory Test Kiln," *Trans. Am. Ceram. Soc.*, **12**, 127 (1910).

pass a 20-mesh sieve. The plastic mass is rolled out on a table to an approximate thickness of $^3/_8$ inch, and a small rectangular indentation formed by pressing with a suitable wooden core. The plaque is then cut to dimensions, dried, and fired to cones 2 to 4 so that it will possess sufficient strength to permit easy mounting of the cones and will stand placing in a hot furnace without disruption.

Mounting Cones.—Plastic china clay mixture is pressed into the rectangular shaped opening of the cone plaque. It is best to undercut the edges slightly so that this plastic mass will not pull out easily. Triangular holes are cut in the clay and the cones inserted with additional clay packed around them. The plaque is marked and placed in the top of the furnace, just over the flame, to dry before placing in the hot furnace. Calcined cones or cones made of calcined materials and gum arabic, and plaques made as above, can be placed in a furnace at a temperature corresponding to cones 20 or 23 without bursting or breaking. Placed as shown in the sketch, we have two duplicate unknown cones with a series of four Orton cones. These are not spaced as recommended in the specifications of the American Society for Testing Materials, but are placed as close together as possible. With calcined materials and good packing, the tendency of the cones to fall on each other is eliminated, and one is more certain of the exact cone deformation, compared with that of the standard Orton cones. By preparing cones and plaques ahead of time and preheating them on the top of the furnace, we can replace plaques of cones in the hot furnace in the minimum time.

Cost of Oxy-Acetylene Apparatus.—The familiar welding torch, pressure gauges and regulator valves so widely used for welding metals, are used. The oxygen and acetylene are shipped in tanks from the factories to any express or freight station. The oxygen tanks are loaned free of charge, while a 300-cubic foot tank for acetylene may be leased for about $75.00. The valves, gauges, regulators, hose connections, and two small lead burning torches cost approximately $105.00. A single large welding torch with the same necessary equipment costs about $140.00 and can be used in place of the two smaller torches, by cutting only a single flame entrance and placing the cone plaque on

a bridge of magnesite. In this case, the flame shoots under the bridge and rises on both sides. Oxygen costs $2.00 per hundred cubic feet and acetylene gas, $3.35. The initial outlay including 300 cubic feet of each gas, will be about $200.00. However, nearly all of the essentials for this equipment will be found in the average well-equipped machine shop or factory and may be used for this purpose.

Gas Consumption.—The following is a typical 5-hour run.

Laboratory number	Cone fused	Oxygen reading, cu. ft.	Acetylene reading, cu. ft.	Time, p. m.
Start	......	150	226	1:10
806	31–32	125	210	2:25
807	31+	117	205	2:45
808	30	110	200	3:10
809	31	105	195	3:30
810	31–32	99	190	3:48
806	31–32	93	185	4:10
807	31+	88	180	4:30
808	30	80	172	4:45
809	31	71	165	5:10
810	31–32	59	163	5:37
KW	28	52.0	160	5:56
11 Heats	Cone 30.8 average	98 cu. ft.	66 cu. ft.	4 hours 46 minutes

Total cost of gas............. $4.17
Cost of gas per heat.......... 0.38

The cost can be cut almost in two by running two *different* unknown cones on the same plaque, a procedure which is warranted when temperatures are uniform and check runs are made.

A speed test run was made, starting with a cold furnace. Cone 26 was deformed in 35 minutes with the consumption of 20 cubic feet of oxygen and 8 cubic feet of acetylene. Cone 32 was deformed five minutes later with a total gas consumption of 28 and 10 cubic feet of oxygen and acetylene, respectively. Greater economy is obtained if a number of tests are run immediately after the original heating.

The average cost of gas used in fusing 300 samples in a period from August 10, 1920 to April 9, 1921, including the experimentation and development of the furnace, was 47 cents per sample.

Time of Heating.—The specifications of the Standard Committee of the American Ceramic Society call for a rate above 800 degrees C not to exceed 10 degrees C per minute. This means about a 76-minute run to the fusion point of cone 28 in addition to the time required to reach 800 degrees C. After carefully comparing the results of first heats which approximate this specified rate, with heats made with a hot furnace, we believe that it is unnecessary to spend this much time at the lower temperatures and that the period where the slow rate of heating is essential, is within two or three cones of the final cones of fusion. If we could revise the specifications, we would consider the following an improvement.

"The rate of heating shall not exceed that corresponding to one-half a cone (approximately 10 degrees C) per minute within a range of ten cones below that of the final fusion cone and this rate shall preferably be decreased to one cone per five minutes within two cones of the final cone of fusion."

Advantages of the Oxy-Acetylene Fusion Furnace

(1) **Simplicity.**—This type has the advantage of the simple construction common to all gas or oil-heated furnaces in contrast to the carbon resistance electric furnace. In the latter type, we found difficulty in maintaining an expensive crucible protection for the cones; also, the electrical contact between the resistor and metal leads was by no means uniform or dependable after a little use. The cone plaque-stand in the gas-fired furnaces can be replaced and any holes in the walls patched while the furnace is hot. Very little time is lost for repairs.

(2) **Ease of Control.**—With a flame which can be thrown in any direction to any part of the furnace and also raised in temperature to a point above 3,000 degrees C, uniform conditions can be maintained around the cones and the temperatures held or varied at will from below cone 10 to cone 42.

(3) **High Temperatures.**—High temperatures which would be impossible with the ordinary gases or fuels of low calorific value can be produced. Studies can be made with the super-refractories.[1]

[1] Washburn and Libman

(4) **Oxidizing Conditions.**—Our best results in terms of clean colors with white, buff, and dark-burning clays have been obtained with the oxygen-acetylene flame. The use of air with its large content of nitrogen makes reducing conditions unavoidable with natural gas flames at the higher temperatures. With oxygen gas in place of the air mixture, the high temperatures can be maintained with the minimum content of reducing gases. With the carbon resistance furnaces it was impossible to keep the high-carbon gases from passing through the crucible and blackening both cones and plaque.

(5) **Comfortable Working Conditions.**—With the small volume of combustion gases rising from the furnace, it is possible to watch the cones deform with the eye at a distance of 15 to 24 inches from the top. This is impossible where the volume of the hot gases is large. In that case it is necessary to take short-time observations from behind insulating screens. With the personal discomfort removed one can maintain the firing conditions with a greater degree of nicety.

(6) **Portable Character.**—The firing equipment, fuel, and even the furnace itself, can be shipped to almost any out-of-the-way locality, factory, or mine. In prospecting a new area for fire clays or running control tests at the mine, this apparatus can be used to save time and expense. Shipments of inferior refractory material can be stopped at the clay bank or mine instead of at the distant factory. The mine foreman can tell within two hours whether a sudden change in the fire-clay seam is for better or worse without sending a sample to a distant testing laboratory.

Other Possibilities.—Hydrogen gas can be used with oxygen to produce a maximum flame temperature of 3,191 degrees C (Richards)[1] and is somewhat cheaper than acetylene and almost as universally obtainable.

Compressed artificial or natural gas fired with oxygen will give higher temperatures than air and the gas, as well as greater ease of handling. The ordinary city gas pressures are too low for high temperature work with the concentrated oxygen.

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College of Mines

[1] Richards, Joseph W., "Metallurgical Calculations," p. 52.

USE OF SPECIAL OXIDES IN PORCELAIN BODIES[1]

By R. F. Geller and B. J. Woods

ABSTRACT

Substitution of special oxides for flint.—The oxides of thorium, titanium and zirconium and the silicate of zirconium were used. Variations in composition were based on batch weights, the percentage of oxide (or silicate) increasing from 27 to 49% with a corresponding decrease in feldspar content. A similar series using flint was also made a basis for comparison.

Effect of special oxides on drying and burning behavior, dielectric strength and resistance to spalling.—(1) *Rutile* causes high drying and burning shrinkage. The burning range is long but softening in every case results above cone 12. Resistance to spalling is above normal. (2) *Thoria* produces a body with a long burning range and great refractoriness. Drying shrinkage is normal, burning shrinkage very high, resistance to spalling very low, and the bodies warp badly. (3) *Zirconia* bodies have a normal drying shrinkage and a high burning shrinkage, no warping, long firing range, and the highest resistance to spalling. (4) *Zircon.*—The zirconium silicate bodies soften at temperatures below cone 18 and the firing range is short. Drying and burning shrinkage are similar to flint bodies but resistance to spalling is above normal.

Effect of oxides on dielectric resistance.—No effect on dielectric resistance is obtained through the use of the special oxides mentioned.

The increasing use of porcelain in many branches of the industry makes the development of special bodies, having one or more properties which adapt them to some particular purpose, of general interest. The present work consisted essentially in substituting the oxides, and in one case the silicate, of comparatively rare elements for flint with a view of increasing the electrical resistivity of the porcelain and the mechanical strength as effected by thermal changes.

For this work the oxides of thorium, titanium and zirconium were used as well as the silicate of zirconium, and a series of bodies was made introducing silica for purposes of comparison. In each case the bodies were prepared according to the following scheme outlined in table 1.

Variations in composition were based entirely on batch weights.

[1]Received April 30, 1921. Published by permission of the Director, U. S. Bureau of Standards.

TABLE 1.—GIVING COMPOSITIONS OF BODIES USED

Body No.	*a* %	*b* %	*c* %	*d* %	*e* %	*f* %	*g* %	*h* %	*i* %	*j* %	*k* %	*l* %	M %
Flint, or compound substituted for it	27	29	31	33	35	37	39	41	43	45	47	49	ZrO_2 35
English china clay	25	25	25	25	25	25	25	25	25	25	25	25	..
Ball clay	10	10	10	10	10	10	10	10	10	10	10	10	5
Kaolin	10	10	10	10	10	10	10	10	10	10	10	10	35
Feldspar	28	26	24	22	20	18	16	14	12	10	8	6	..
Calcine No. 14	..	..	..	..	..	..	..	..	..	..	..	..	25

Body M is independent of the series and is explained later. The rutile was given seven hours grinding in a ball mill before being mixed with the other ingredients of the body. This was necessary because of its high specific gravity and its extreme hardness, which properties would not permit its being ground sufficiently fine in the ordinary course of preparation. After this preliminary grinding the rutile bodies were prepared the same as the others, *i. e.*, the ingredients were mixed, ground wet in a ball mill for three hours and screened through a 150 mesh sieve. Cups for the dielectric test were prepared both by jiggering and casting. Specimens for draw trial firing were made by forming the thoroughly hand pugged body in brass molds. The specimens were of one inch cross section by two inches long. Each piece was marked on opposite sides with a gauge having points exactly five centimeters apart for the determination of linear shrinkage in drying and burning. These pieces were carefully dried and two samples of each body were fired to cones 6, 8, 10, 12, 14 and 16, respectively, in a draw trial burn. The drying and firing shrinkage, water loss in drying, and porosity in the burned state were determined on each piece in the customary manner. Two specimens of each body were also burned to 1250°C and allowed to cool with the kiln. A spalling test was made on these pieces in the following manner: The specimens were heated to 500°C in an electric furnace and plunged into running water. This procedure was repeated until failure occurred, the number of immersions at which the pieces actually fell apart or could easily be broken with the fingers being noted.

Results

Rutile as a substitute for flint.—In the first group of bodies rutile was used as the substitute for flint. The material employed contained 95% TiO_2, the balance being made up of impurities high in iron. Table 2 presents in detail the data obtained, and from this it can be seen that drying and burning shrinkage are slightly high as compared with the flint bodies. (For results from flint series see table 6 and figure 5.) Figure 1

TABLE 2.—NUMBERS INDICATE PER CENT IN TERMS OF PLASTIC CLAY WITH THE EXCEPTION OF "POROSITY" WHICH IS IN TERMS OF THE FIRED WEIGHT

Rutile bodies

	Cone 16				Cone 14				Cone 12				
Body No.	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Maturing temp. in cones
b	3.7	X	18.5	X	4.7	X	19.0	X	5.0	13.2	19.1	0.40	6
d	5.2	X	18.8	X	5.1	X	19.2	X	5.3	14.3	19.0	0.41	6
f	3.8	X	17.1	X	5.4	X	17.5	X	5.7	15.2	17.5	0.00	6
h	6.4	X	18.3	X	6.3	X	19.0	X	5.7	16.6	18.8	0.43	8
l	5.0	X	18.9	X	5.0	X	18.7	X	5.0	15.0	18.8	0.42	8
j	4.7	X	18.7	X	4.4	X	18.9	X	4.7	14.2	19.0	0.44	10
	Cone 10				Cone 8				Cone 6				
b	5.4	14.6	19.1	0.42	4.6	13.3	19.1	0.42	4.6	14.6	19.2	0.42	6
d	5.5	14.8	18.9	0.41	5.6	14.8	18.9	0.21	5.0	14.5	19.5	0.66	6
f	4.3	12.9	16.6	0.00	5.2	14.7	18.3	0.31	4.9	12.9	17.2	0.42	6
h	5.1	16.0	18.4	0.44	4.4	14.4	17.9	0.43	5.2	15.6	18.6	3.50	8
j	5.0	15.1	18.7	0.21	5.0	13.7	18.9	0.42	4.7	13.5	18.9	3.92	8
l	4.9	15.0	19.0	0.84	4.7	13.3	19.3	1.51	4.7	13.3	19.0	9.30	10

shows graphically the burning behavior of the rutile series. Although the maturing temperature is as low as cone 6, the bodies have a long burning range to cone 12. Beyond this point they are without exception so softened and deformed that no measurement can be obtained. Below C 12 the bodies retain the dark buff color of the rutile and at higher temperatures burn from light brown to black.

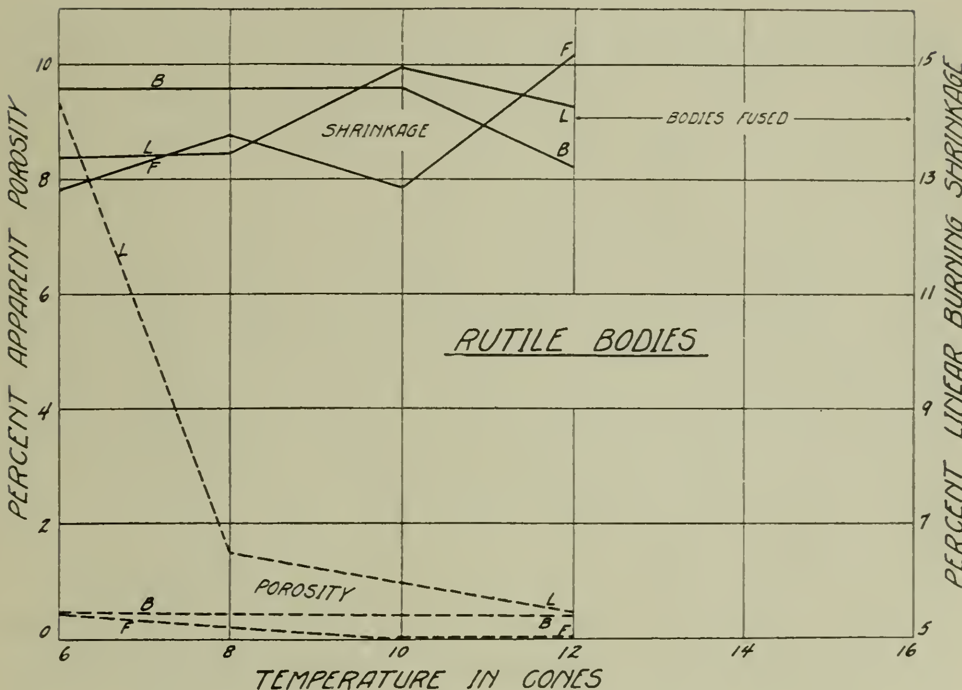

RUTILE BODIES
SHRINKAGE
POROSITY
BODIES FUSED
PERCENT APPARENT POROSITY
PERCENT LINEAR BURNING SHRINKAGE
TEMPERATURE IN CONES

FIG. 1.

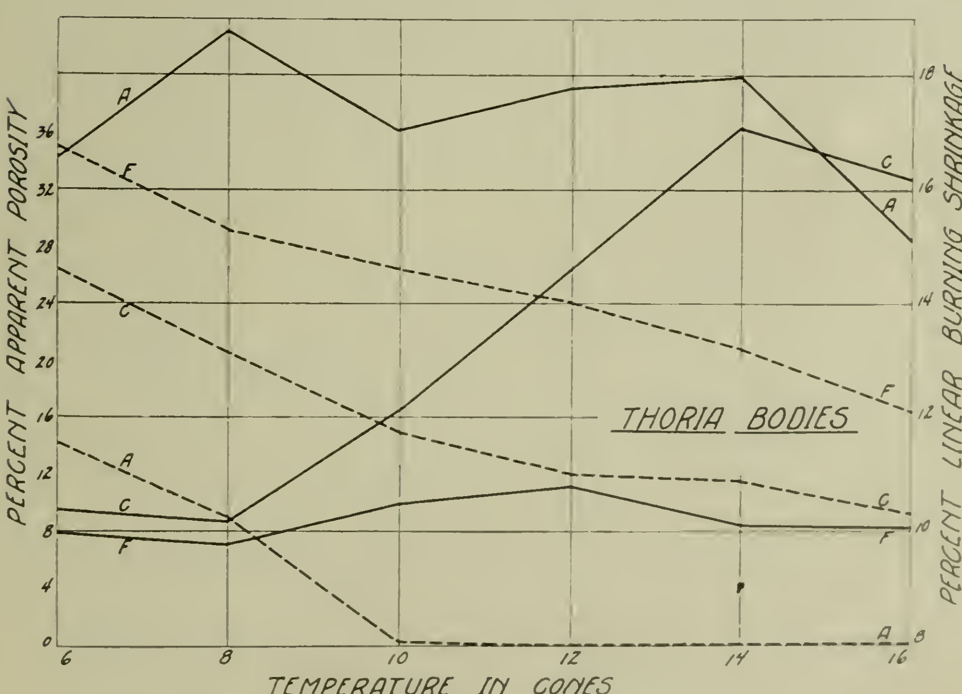

THORIA BODIES
PERCENT APPARENT POROSITY
PERCENT LINEAR BURNING SHRINKAGE
TEMPERATURE IN CONES

FIG. 2.

Thoria as a substitute for flint.—Using thoria in place of flint a group of bodies were obtained having a long burning range and high refractoriness. Due to the small amount of thoria on hand only the first six bodies of the series, in which the thoria content varies from 27 to 37 per cent, were made. The only body reaching maturity was that containing the lowest percentage of thoria, 27 per cent, and with increasing amounts of this oxide the resistance to heat rapidly increases so that with 37 per cent, the body, at cone 16 has a porosity of over twelve per cent. Shrinkage is comparatively low with the higher amounts of thoria but increases rapidly with a decrease of the oxide, varying from ten to approximately sixteen per cent at cone 16. Even though vitrification has not been reached, the bodies seem to undergo a decided expansion above cone 14. A tendency to warp is also noticeable in tests from every draw trial giving the specimens a shriveled appearance, particularly in trials fired above cone 12. The bodies vary in color from a faint pink to dead white.

Zirconia as a substitute for flint.—In the third series zirconia, containing approximately 98 per cent ZrO_2, was substituted for flint. The data obtained are shown by table 4 and figure 3. The dry-

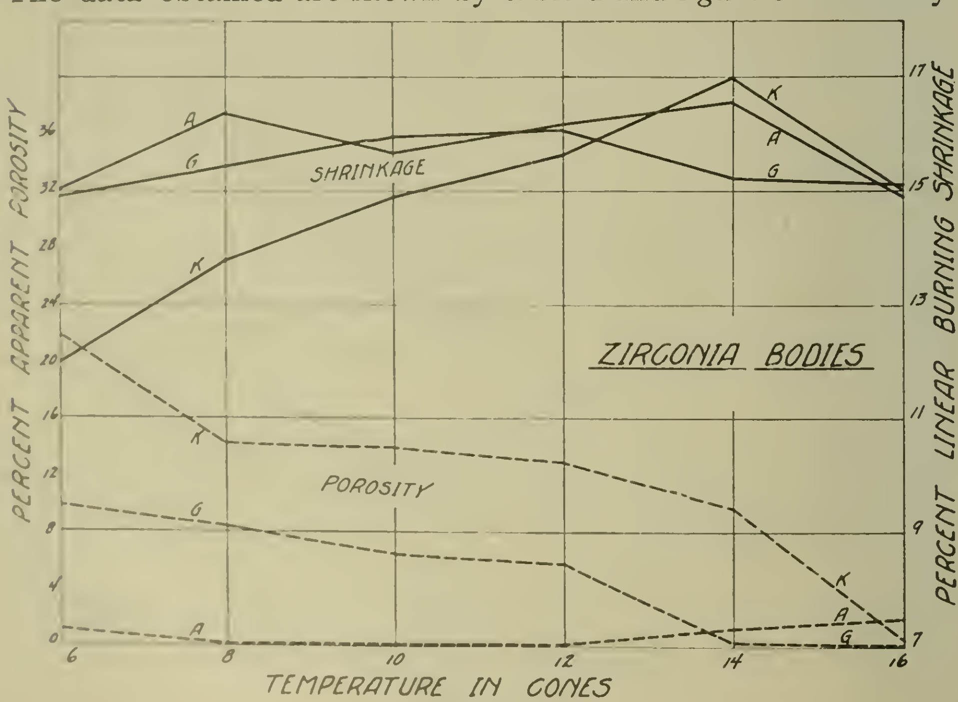


FIG. 3.

TABLE 3.—NUMBERS INDICATE PER CENT IN TERMS OF PLASTIC CLAY WITH THE EXCEPTION OF "POROSITY" WHICH IS IN TERMS OF THE FIRED WEIGHT

Thoria bodies

Body No.	Cone 16				Cone 14				Cone 12				Maturing temp. in cones
	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	
a	5.8	15.1	22.3	0.07	6.1	18.0	22.1	0.24	5.6	17.8	22.5	1.92	14
b	6.6	16.8	22.5	5.4	6.6	19.0	22.9	9.4	6.6	19.5	22.5	10.7	16+
c	5.9	16.2	23.4	9.12	6.0	17.1	23.5	11.6	4.7	11.3	23.4	12.6	16+
d	X	12.0	24.3	10.1	X	9.9	23.2	12.0	X	10.0	23.2	15.8	16+
e	6.0	12.2	25.2	12.6	6.2	12.1	25.8	16.0	6.4	12.5	25.2	17.3	16+
f	4.7	10.0	25.8	16.3	4.8	9.8	25.5	20.9	5.0	10.5	25.6	24.2	16+
	Cone 10				Cone 8				Cone 6				
a	6.7	17.0	22.5	2.25	6.0	18.8	22.5	9.15	5.1	16.7	22.5	14.2	14
b	6.1	15.7	22.9	13.3	6.7	16.3	3.0	15.9	5.7	13.0	22.5	23.1	16+
c	4.6	12.1	23.4	15.1	4.6	10.2	23.5	20.7	4.8	10.4	23.1	26.4	16+
d	X	11.9	23.6	20.4	X	X	23.9	X	X	X	24.5	X	16+
e	5.7	10.9	26.2	23.7	5.7	12.6	25.7	25.2	5.4	10.4	25.8	27.5	16+
f	5.3	10.8	25.8	26.3	5.5	10.2	25.9	29.2	5.3	10.1	26.4	33.3	16+

TABLE 4.—NUMBERS INDICATE PER CENT IN TERMS OF PLASTIC CLAY WITH THE EXCEPTION OF "POROSITY" WHICH IS IN TERMS OF THE FIRED WEIGHT

Zirconia bodies

Body No.	Cone 16				Cone 14				Cone 12				Maturing temp. in cones
	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	
a	5.1	15.4	17.7	0.98	6.6	16.8	17.8	0.64	5.4	16.1	17.8	0.04	6
b	5.0	15.0	18.3	0.00	2.7	15.2	17.8	X	2.8	16.6	17.5	0.00	8
c	4.0	14.2	18.7	X	3.8	14.3	19.3	0.04	4.4	16.1	18.7	0.21	10
d	4.0	14.2	18.1	0.10	3.6	15.3	18.1	0.10	3.4	14.6	18.0	0.25	10
e	4.2	14.4	19.2	0.20	4.5	15.3	19.5	0.86	4.0	15.5	19.7	0.13	10
f	3.0	13.2	18.6	0.12	3.7	13.7	19.2	0.28	4.6	15.9	19.2	1.34	14
g	5.4	15.1	19.3	0.06	5.0	15.2	19.0	0.28	5.8	16.0	20.2	5.79	14
h	3.4	13.9	19.2	0.30	3.3	14.2	19.3	0.31	4.1	15.5	19.4	9.1	14
i	4.9	14.1	18.6	0.16	3.4	14.1	18.9	0.84	4.5	15.9	19.6	9.24	14
j	6.2	15.4	20.8	2.53	6.5	15.1	21.0	4.86	5.8	15.6	20.7	12.70	16+
k	4.6	14.9	20.1	0.19	4.2	17.0	19.5	4.38	4.5	15.7	20.0	19.50	16
l	3.8	13.2	18.2	2.09	3.8	13.1	19.2	9.82	4.1	14.3	18.9	14.30	16+

TABLE 4 (*Continued*)

	Cone 10				Cone 8				Cone 6				
a	5.0	15.7	17.9	0.00	6.0	16.2	18.4	0.11	4.3	15.0	17.8	0.89	6
b	2.8	15.3	17.4	0.00	2.7	15.9	17.7	0.36	3.6	15.4	17.4	X	8
c	4.4	16.1	19.5	0.13	4.4	17.0	19.9	0.19	4.3	16.2	18.9	3.10	10
d	4.2	15.9	17.9	0.17	3.6	15.4	17.6	0.32	3.3	14.2	17.6	6.16	10
e	4.5	16.0	19.4	0.00	4.6	16.8	19.2	1.46	4.2	15.2	18.8	8.22	10
f	4.3	16.2	18.2	1.75	4.5	16.1	18.5	4.05	4.0	14.5	18.3	13.10	14
g	5.8	16.0	20.0	6.51	4.8	14.5	19.2	8.62	6.1	15.0	19.3	8.97	14
h	4.0	16.5	19.7	7.70	4.1	13.4	19.5	9.13	4.4	14.6	19.8	9.00	14
i	4.1	16.2	19.5	9.35	4.4	15.6	19.3	10.50	4.5	15.4	19.2	12.10	14
j	5.6	15.6	20.8	11.00	6.2	16.3	20.8	12.60	5.4	15.6	20.8	16.90	16+
k	4.7	14.9	19.7	14.12	4.4	13.8	19.8	14.30	4.4	12.0	19.6	21.80	16
l	4.7	14.3	18.9	15.50	5.0	13.6	18.9	14.70	4.3	13.1	18.8	17.70	16+

ing shrinkage and water of plasticity are about the same as for the flint bodies, while the burning shrinkage is the highest obtained next to the thoria bodies. Unlike the thoria series, however, these specimens show no warping or blistering at any stage. The color of the burned body is uniformly good and after vitrification shows a very tough fracture. As the graphs in figure 3 show, the shrinkage, although high, is very uniform considering the range of temperature and the wide variation in the per cent of the refractory constituent. The porosity curves also are comparatively uniform and lie quite closely together. Although the bodies low in zirconia are vitrified at cone temperatures 6 to 10, there is no harmful overburning evident at the highest heat reached in this work.

Since the zirconia produced a body of good burning properties and excellent structure, it was decided to duplicate the work with zircon, which is the naturally occurring mineral $ZrSiO_4$. This material was approximately 95% pure, washed iron free, and considerably cheaper than zirconia. Although the same batch weights of the silicate of zirconium were used as for the oxide, the acid-base ratios in the empirical formula were not changed very decidedly since both the silica and zirconia, which theoretically constitute the silicate, belong to the RO_2 group. This is shown by the following formulas:

Body A

Using ZrO_2		Using $ZrSiO_4$	
	$13.0\ SiO_2$		$15.7\ SiO_2$
$1.00\ K_2O : 4.5\ Al_2O_3 :$		$1.00\ K_2O : 4.5\ Al_2O_3 :$	
	$4.2\ ZrO_2$		$2.5\ ZrO_2$

Body B

	$25.4\ SiO_2$		$38.2\ SiO_2$
$1.00\ K_2O : 10.75\ Al_2O_3:$		$1.00\ K_2O : 10.75\ Al_2O_3:$	
	$22.4\ ZrO_2$		$12.8\ ZrO_2$

TABLE 5.—NUMBERS INDICATE PER CENT IN TERMS OF PLASTIC CLAY WITH THE EXCEPTION OF "POROSITY" WHICH IS IN TERMS OF THE FIRED WEIGHT

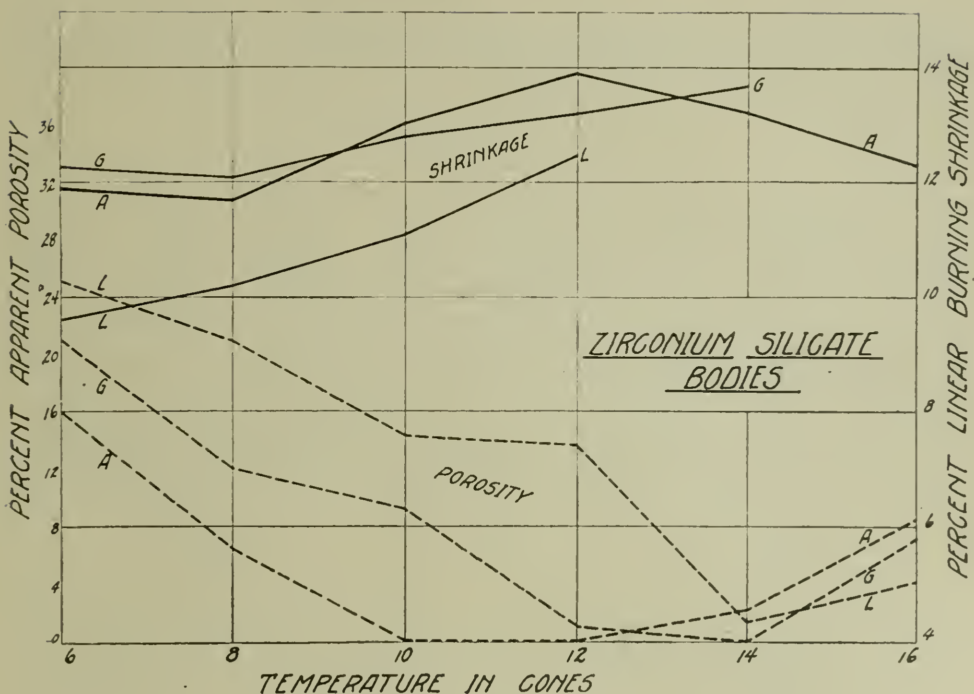
Zirconium silicate bodies

	Cone 16				Cone 14				Cone 12				
Body No.	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Drying shrinkage	Burning shrinkage	Water of plasticity	Porosity	Maturing temp. in cones
	%	%	%	%	%	%	%	%	%	%	%	%	
a	5.4	12.3	18.8	8.53	5.1	13.2	19.2	2.33	5.0	13.8	18.8	0.66	10
b	3.9	10.4	18.0	7.14	4.2	11.9	18.0	0.83	4.1	13.1	17.7	1.46	10
c	2.9	10.2	16.0	8.20	3.3	11.0	16.1	1.03	3.3	11.4	16.0	0.61	12
d	3.9	12.3	17.1	6.36	4.4	13.6	17.6	0.21	4.4	X	17.0	0.09	12
e	4.5	X	17.2	8.6	4.1	14.4	17.9	0.42	4.0	12.7	17.7	0.41	12
f	5.2	X	17.7	4.79	4.5	12.8	17.8	0.42	4.8	12.8	17.9	5.27	14
g	4.0	X	18.9	7.30	4.2	13.7	19.0	0.44	3.9	13.2	18.4	1.07	14
h	5.0	X	18.7	6.86	5.0	15.2	18.0	0.43	5.0	13.8	18.9	2.42	14
i	5.2	X	17.0	3.02	5.2	14.2	17.2	0.20	5.3	13.5	17.2	12.10	14
j	5.2	12.4	16.6	6.50	4.6	12.3	17.2	0.83	5.3	13.0	17.1	7.80	14
k	5.0	X	17.3	0.62	5.5	13.8	17.3	3.28	5.5	13.3	17.3	8.75	16
l	5.0	X	16.8	3.98	5.1	X	16.9	1.41	5.5	12.5	16.8	13.90	14
	Cone 10				Cone 8				Cone 6				
	%	%	%	%	%	%	%	%	%	%	%	%	
a	5.0	13.0	18.7	0.66	4.7	11.7	18.5	6.59	5.3	11.9	18.9	15.90	10
b	3.9	11.9	17.8	0.8	4.3	11.2	17.7	8.04	4.0	9.5	17.8	19.40	10
c	3.0	11.0	16.0	3.80	3.0	11.2	16.0	7.21	3.4	9.8	16.5	19.40	12
d	3.9	12.3	17.1	5.40	3.9	11.9	17.2	10.00	4.7	11.9	17.6	17.00	12
e	4.2	12.5	17.7	6.20	4.0	10.5	17.7	13.20	4.2	9.7	17.3	18.90	12
f	4.6	11.6	18.1	5.43	4.2	10.6	18.1	15.00	4.0	9.5	18.0	22.40	14
g	4.2	12.8	19.0	9.10	4.5	12.1	19.0	12.10	4.4	12.3	18.9	21.30	14
h	5.1	12.2	18.9	9.33	5.3	11.8	19.0	17.20	5.2	10.9	19.0	24.90	14
i	5.3	12.7	17.4	12.30	4.9	11.1	17.2	16.70	5.4	10.0	17.3	24.90	14
j	4.9	12.5	17.1	13.20	5.5	11.8	17.2	15.40	5.1	10.2	16.9	23.20	14
k	5.5	12.5	17.3	4.28	5.5	11.8	17.4	19.20	5.5	10.0	17.1	25.30	16
l	5.0	11.1	16.8	13.90	5.1	10.4	16.7	21.00	5.4	9.6	16.9	25.10	14

The color of the draw trials vary from a faint gray at cone 6 to a yellow brown at cone 16. At the higher temperatures the specimens tend to warp and blister. This tendency to distort in burning increases with increasing amounts of $ZrSiO_4$ although the refactoriness is also increased. As the graph indicates, linear shrinkage can not be obtained on the bodies high in silicate due to this distortion, while all the bodies have softened considerably at cone 16 with the exception of the two highest in zircon. The fact that these bodies soften at temperatures lower than those of the zirconia bodies is no doubt due to the formation of a eutectic between zircon and cristobalite form of silica. This eutectic has been given as probably lying close to the molecular proportion of 10 ZrO_2 and 90 SiO_2. Its melting temperature has not as yet been determined. The firing range of the zircon bodies is comparatively short and shows serious overburning at cone 16.

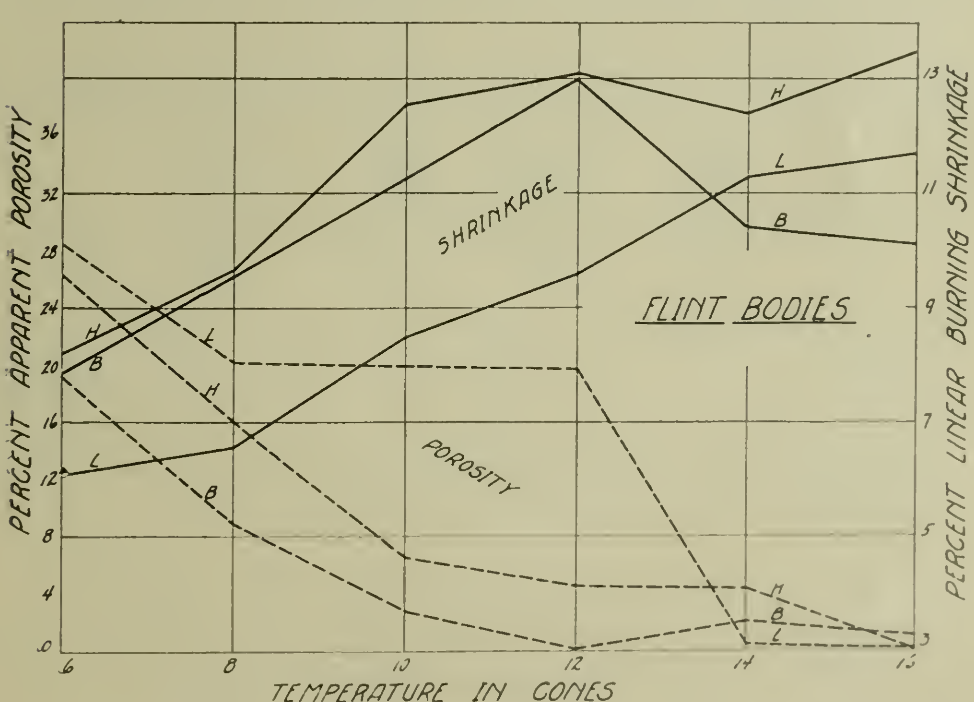
Considering the general firing behavior of these bodies then, as compared with the flint series, we find that the rutile series have a rather long range but soften rapidly above cone 12. Thoria on the contrary produces an extremely refractory body which also has a long firing range but a soft structure. Zircon tends to form a eutectic which causes the bodies to have a narrow maturing range and also causes warping and blistering. The zirconia bodies do not overburn and the firing range compares very favorably with the flint series. The structure is hard and the fracture appears very tough. From the data given in table 7, we see that a zirconia content as low as 35 per cent produces a body of maximum toughness which matures at cone 10–12. The resistance of the bodies to sudden temperature changes is on the whole very satisfactory, being more than four times as great as that of the flint body, according to the results of the spalling tests. Although the various oxides affect the mechanical strength of porcelain considerably, it is evident that the electrical resistivity is practically the same for all, including the flint body (see table No. 7). The resistivity is shown by the "TE" value. This figure indicates the temperature in degrees Centigrade at which a cubic centimeter of the material still shows a resistance of one megohm.[1] Due to lack of material cups were not made of the

[1] This Journal, 1, 600 (1918).



ZIRCONIUM SILICATE BODIES
SHRINKAGE
POROSITY
PERCENT APPARENT POROSITY
PERCENT LINEAR BURNING SHRINKAGE
TEMPERATURE IN CONES

FIG. 4.



FLINT BODIES
SHRINKAGE
POROSITY
PERCENT APPARENT POROSITY
PERCENT LINEAR BURNING SHRINKAGE
TEMPERATURE IN CONES

FIG. 5.

Table 6.—Numbers Indicate Per Cent in Terms of Plastic Clay with the Exception of "Porosity" Which Is in Terms of the Fired Weight

Body No.	Cone 16 Drying shrinkage	Cone 16 Burning shrinkage	Cone 16 Water of plasticity	Cone 16 Porosity	Cone 14 Drying shrinkage	Cone 14 Burning shrinkage	Cone 14 Water of plasticity	Cone 14 Porosity	Cone 12 Drying shrinkage	Cone 12 Burning shrinkage	Cone 12 Water of plasticity	Cone 12 Porosity	Maturing temp. in cones
b	4.0	10.1	15.9	1.04	4.0	10.4	18.4	2.50	4.0	13.0	18.5	0.41	12
d	4.4	12.0	19.7	0.36	4.2	12.1	18.8	4.30	4.6	13.3	18.6	0.70	12
f	5.1	12.1	19.2	0.36	4.9	12.8	19.3	2.60	5.3	13.3	19.6	1.20	16
h	6.0	13.4	20.0	0.20	5.3	12.4	19.8	4.77	5.7	13.1	19.7	4.76	16
j	4.8	13.7	20.1	2.40	4.3	12.7	20.0	1.22	3.8	10.8	19.8	8.30	16+
l	4.0	11.7	19.4	3.15	4.5	11.3	19.8	2.15	3.7	9.6	19.8	20.00	16+

Body No.	Cone 10 Drying shrinkage	Cone 10 Burning shrinkage	Cone 10 Water of plasticity	Cone 10 Porosity	Cone 8 Drying shrinkage	Cone 8 Burning shrinkage	Cone 8 Water of plasticity	Cone 8 Porosity	Cone 6 Drying shrinkage	Cone 6 Burning shrinkage	Cone 6 Water of plasticity	Cone 6 Porosity	Maturing temp. in cones
b	3.4	11.2	18.3	3.02	3.5	9.6	18.3	9.05	3.7	7.7	18.1	19.40	12
d	4.4	13.3	19.4	4.40	4.7	12.1	19.2	6.60	4.2	12.0	19.1	19.70	12
f	5.7	12.9	19.5	6.70	5.4	10.0	19.3	14.30	5.4	8.3	19.2	26.00	16
h	5.6	12.6	19.8	6.49	4.7	9.6	20.0	16.10	4.3	8.2	20.1	26.60	16
j	4.7	10.6	20.0	6.56	5.4	11.8	20.5	16.50	4.4	7.9	20.1	26.50	16+
l	5.0	8.5	19.5	21.30	4.9	6.6	19.7	23.50	4.2	6.1	19.6	28.40	16+

Table 7.—Showing Results of Spalling Test, and Electrical Resistivity

Body No.	Number of immersions required to cause— cracks (Zirconia series)	failure	Number of immersions required to cause— cracks (Rutile series)	failure	Number of immersions required to cause— cracks (Thoria series)	failure	Number of immersions required to cause— cracks (Zirconium silicate series)	failure	Number of immersions required to cause— cracks (Flint series)	failure	Body M
a	16	32	. .	. .	2	14	6	10	4	5	
b	16	22	7	10	2	21	8	9	3	5	
c	16	32	. .	. .	2	19	6	7	3	6	Maturing
d	16	48	7	8	2	22	8	9	3	5	Temp.C14
e	20	50+	. .	. .	2	15	9	10	3	6	"Te" value
f	20	50+	6	8	2	17	7	9	3	4	= 610
g	20	50+	. .	. .	. .	. .	8	9	4	6	
h	20	50+	6	7	. .	. .	9	10	4	5	
i	17	31	. .	. .	. .	. .	8	9	3	7	
j	17	50+	7	9	. .	. .	8	9	3	5	
k	17	29	. .	. .	. .	. .	8	12	2	4	
l	17	50+	9	12	. .	. .	9	10	2	4	
"Te" value	Body f 390		Body f 370		Body f . .		Body f 390		Body f 390		

thoria body and its resistivity is consequently not known, but its poor mechanical strength, high maturing temperature and the initial cost of the thoria would tend to make it undesirable practically. As compared with flint, the zircon body has satisfactory toughness and resistivity, but it is far inferior to that of zirconia in mechanical strength. It has been shown by Bleininger and Riddle[1] that alkalies tend to reduce the resistivity of porcelains, which explains the low resistivity of these bodies. Consequently a single body was prepared substituting ZrO_2 for flint, for mechanical strength, and a prepared flux for the spar. The composition is shown in table 1 as body M. The calcine No. 14 was composed of the theoretical substance $MgO.Al_2O_3.4SiO_2$ and was made by heating 18.2% $MgCO_3$, 56% kaolin and 25.8% flint to cone 13. This body fired to a good color and did not tend to warp. Made up as crucibles and tested for spalling, it proved to have good structure and the fracture was similar in appearance to the zirconia bodies. The effect of the elimination of the feldspar on the electrical conductivity of the porcelain is obvious, the "TE" value having been raised from a mean value of less than 400 to 610. The porcelain resembles those in which flint is replaced by sillimanite. Not sufficient variation between cast and jiggered cups is noticeable to warrant any statement concerning the effect of the method of manufacture on resistivity.

Conclusions

From a study of the data and observations given above it may be said that:

(*a*) Rutile, of the purity used does not materially increase the mechanical strength and causes the body to have undesirable firing properties.

(*b*) Thoria causes the porcelain, in which it is substituted for flint, to be very sensitive to thermal changes. The firing range is long, but exceptionally high temperatures are required for vitrification.

(*c*) Zirconia, when used in porcelains as a substitute for flint and within the percentages observed in this work, produces a body of excellent mechanical strength and firing qualities.

[1] *Ibid.*, 2, 564 (1919).

(*d*) The vitrification of these bodies through the agency of the feldspar is not influenced to any great extent by the presence of the refractory oxides. They merely behave as inert bodies and the compositions containing them vitrify at higher or lower temperatures according to the feldspar content. There appears to be in general no increase in the refractoriness of the body as compared with a body containing an equal amount of quartz, although in the case of thoria there seems to be some hardening of the vitrifying matrix.

(*e*) The several oxides used in this work do not affect the electrical resistivity of the porcelain in which they are incorporated.

(*f*) A desirable porcelain for electrical purposes can be produced by substituting zirconia for flint (since zirconia is practically unaffected by thermal changes), and using a prepared flux as described to nullify the effect of feldspar on the resistivity.

The writers wish to acknowledge the assistance given them by Mr. A. V. Bleininger, in outlining this work.

BUREAU OF STANDARDS,
WASHINGTON, D. C.
FEBRUARY, 17, 1921

CERAMIC ABSTRACTS

Author Index to Abstracts for October

General and Miscellaneous

1. **Successful operation of a waste heat dryer.** J. H. Kruson. *Brick Clay Record*, **59**, 266–268 (1921).—Clays may be divided into three groups as regards their drying behavior. A-Clays that will not dry safely in a circulating atmosphere; B-Clays requiring a low temp. or nearly saturated condition on entering a moving atmosphere; and C-Clays requiring a heating chamber in a stagnant non-drying atmosphere before they enter a slow drying atmosphere. For the month of Jan. 5,983 cu. ft. of air held one lb. of H_2O whereas in July only 1,127 cu. ft. were required to hold the same amt. As weather conditions change some adjustment must be made in temp. or the vol. of incoming air in order that an even amt. of H_2O be evaporated.

H. G. Shurecht

2. **Shrinkage on drying kaolins and clays.** A. Bigot. *Compt. rend.*, **172**, 755–8 (1921).—Small test specimens were made from a number of kaolins and clays of French origin, usually molded by hand in plaster molds from a soft paste; a few specimens were formed in steel molds under pressure. The specimens were dried in air and finally at 110°, detn. of length and wt. being made at intervals. The water given off while the specimen was shrinking was called colloidal water; that given off after shrinkage had ceased, interposed (pore) water. A number to express the *plasticity* of the clay was obtained by dividing the wt. of colloidal water by the wt. of total water and multiplying by the shrinkage. The chemical analyses, colloidal water, total water, contraction, and plasticity numbers of the clays examd. are given in a table.

J. S. Laird (*C. A.*)

3. **Georgia (kaolin) clays and their development.** T. P. Maynard. *Manufacturers' Rec.*, **78**, No. 10, 135–9 (1920).—The white clay deposits of Georgia are very extensive, occurring largely in the coastal plain. The kaolin mined has been used largely in the manuf. of paper, but also in rubber goods, paints, pottery. The clays are sedimentary and plastic, but vary widely in their properties and in compn. from typical kaolin to bauxite. J. S. Laird (*C. A.*)

4. **Ruggles-Coles dryer.** H. Jordan. *Feuerungstechnick*, **9**, 31–3(1920).—The construction and operation of various forms of Ruggles-Coles driers are discussed with photographs and drawings of the various classes. Also in *Chem. App.* **8**, 32–4 (1921). H. C. Parrish (*C. A.*)

PATENTS

5. **Shaping device for articles made of ceramic bonded material.** Pehr Johanson and Ernest A. Francke. U. S. 1,376,773, May 3, 1921. A device for shaping articles of bonded material, having a projecting center to form a center hole in the article, a blade rotatably mounted on the device, and means for the blade while rotating to move bodily toward the work to a predetermined extent and thereafter to freely rotate without substantial movement toward the work.

6. **Drying-kiln.** Sidney E. Cornish. U. S. 1,376,319, April 26, 1921. A kiln, with fans at one side, and flues connecting the fans with the other side of the kiln, whereby a continuous circuitous circulation of air is provided transversely through the kiln.

7. Method of making clay and graphite crucibles. JEAN HUBERT LOUIS DEBATS. U. S. 1,374,909, April 19, 1921. The method of making crucibles or pots containing clay, which consists in mixing non-ferrous metal with the material from which the crucible or pot is formed, and forming the crucible or pot therefrom, whereby in the use of the crucible or pot the metal forms a metallic silicate coating on the surface thereof. C. M. SOEGER, JR.

BOOK

8. Taschenbuch für keramiker 1921. Berlin: Verlag Keramische Rundschau G. m. b. H. M8. For review see *Tonind.-Ztg.* **45,** 37(1921). (*C. A.*)

Apparatus and Instruments

9. Instrument determines carbon dioxide and detects carbon monoxide ANON. *Elec. Rev.* (Chicago), **78,** 634–6(1921).—A discussion of combustion and the efficiency from analyses. Curves show the relation of flue-gas heat loss to the % CO_2, and the relation when combustibles appear at 14% CO_2. An app. is described that analyzes and records the CO_2 present at all times in flue gases, simultaneously detecting and recording the presence and approximate proportion of combustible gases. Actual percentages are rarely less than $^2/_3$ or more than equal to the amts. recorded. The instrument is driven by water pressure. Gas samples are passed through the filtering system, and then forced through the app. by means of a Hg piston. The gas is passed alternately through two routes, one directly through a KOH tank and the other first through an elec. furnace wherein combustible gases are oxidized to CO_2 and H_2O, and then through the KOH tank. The difference in readings is proportional to the amt. of combustible gas present. In the elec. furnace, the O is taken from the air invariably present in flue gases, or from CuO provided in the furnace. Communicating tubes are used to diminish the lag between the time the gas leaves the flue and when the analysis is recorded on the chart. The app. is dirtproof and requires little attention.

W. H. BOYNTON (*C. A.*)

10. A comparison of monochromatic screens for optical pyrometry. W. E. FORSYTHE. Nela Research Lab., Cleveland, O. *J. Optical Soc. Am.*, **5,** 85–95(1921).—Screens of Jena red glass, a Corning Co. green glass, and blue uviol glass were compared to find their relative efficiency. Reasons are given for preferring red glass. (*C. A.*)

11. Mixing. OTTO STIER. Heidelberg. *Chem. Ztg.*, **44,** 902–5(1920).—A survey of the recognized com. methods for mixing liquids with liquids, liquids with solids, and solids with solids. This includes descriptions of shaking, stirring, and air-current methods for liquids and sludges; kneading and churning for plastic masses; and shaking, stirring and rotating for solids. Numerous diagrams and explanations are given to show approved app. and equipment. C. C. DAVIS (*C. A.*)

Chemistry, Physics and Geology of Raw Materials

12. Prism hardness; new test of hardness. B. P. HAIGH. *J. Inst. Mech. Eng.*, **7,** 891–913(1920).—The significance of the term hardness is discussed

and the principles of the new method explained. The test pieces consist of square prisms placed cross-wise with their edges in contact and subjected to a measured load. For small indentations the form of indentation was found to be independent of the load and reproducible values were obtained by dividing the loads by the squares of any characteristic linear dimension of the indentation. The values found were independent of the angle of the prism. The apparatus is described together with results obtained with different metals.

ED.

13. **Colloid chemistry of clays and clay products.** A. B. SEARLE. *3rd. rep. on colloid chem. and its gen. and ind. appl.* Brit. Depart. Sci. Ind. Res. 113–153 (1920).—A review of the present state of our knowledge. ED.

14. **Viscosity and flocculation of coarse suspensions.** HANS EGNÉR. *Meid. K. Vetenskapsakad. Nobelinst.*, **4**, No. 4, 27 pp.—It is shown by viscosity measurements that no general formula for calcg. the viscosity of a suspension from its volume concn. is generally satisfactory. The properties of suspensions are shown to resemble closely those of suspension colloids. They are generally negatively charged and show characteristic electric endosmosis, cataphoresis, etc. Electrolytes have a great effect upon the state of these coarse suspensions. Cations flocculate and increase the viscosity and sedimentation height. Anions act in the opposite direction. With the exception of OH ions, which act irregularly, the magnitude of their flocculation power generally changes according to Hardy's law. (Cf. *C. A.* **14**, 1916.)

A. E. STEARN (*C. A.*)

15. **The colloidal character of clays and their practical application.** ALBERT BENCKE. *Sprechsaal*, **53**, 490–491 (1920).—By means of the ultra-microscope the colloidal matter in clays may be identified. When a salt solution as NH_4Cl, $BaCl_2$, $Al_2(SO_4)_3$ and $CuSO_4$ is allowed to stand in contact with clay a definite amt. of the basic ions are adsorbed by the clay. For ex. 1 gr. of kaolin adsorbs 0.0038 to 0.0169 grs. of CuO from a 50 cc. sol. containing 2 grs. of $CuSO_4$. 0.077 grs. NH_4 from NH_4Cl, 0.373 grs. Ba from $BaCl_2$ and 0.075 grs. Al from $Al_2(SO_4)_3$ are adsorbed from a 0.1 n. sols. in 3 das. Certain organic compounds, as tannin, have a deflocculating effect on clays. Tannin also acts as a protective colloid and to a certain extent prevents deflocculation by alkalies. The addition of a small amt. of Al_2Cl_6 or tannic acid to kaolins increases the plasticity decidedly while alkalies have the opposite effect. Upon calcining clays to 500°–900° C, irreversible colloids are formed. Upon driving off the chem. H_2O the clay combines with SO_2 and SO_3, thus acting as a catalyser in the oxidation of SO_2 to SO_3. This property of clay will make it valuable as a catalyser in many chem. reactions. During the dehydration of clays the reaction is endothermic but upon heating above 900°C it is exothermic. At this point the clay is probably decomposed into $Al_2O_3.SiO_2$ and SiO_2. Upon further heating the clay gradually becomes a liquid and the surface tension plays an important rôle. H. G. SCHURECHT

16. **Solution and growth forms of quartz from sodium tetraborate solutions heated under pressure.** GABRIEL LINCIO. Turin. *Beitr. Kryst. Miner-*

alogie, **1**, 87–101 (1916).—The Spezia app. for heating minerals in contact with solns. under pressure was used. Spheres of quartz were placed in this, one above and one below a vessel containing quartz fragments, and the whole was surrounded by a 6% aq. soln. of $Na_2B_4O_7$. In the growth chamber the temp. reached about 170°, in the soln. chamber 320°. Chem. reaction occurs between the quartz and the borax, apparently with the formation of a Na borosilicate. After 25 days the app. was opened and the growth and soln. figs. on the respective spheres were studied. The trigonal character of the mineral is strikingly brought out, and conclusions can be drawn as to the *mechanism of soln. and deposition processes* from the features exhibited.

E. T. W. (*C. A.*)

17. The silicate chemist in industry. C. Loeser. *Chem. Ztg.*, **44**, 955–6 (1920).—The silicate chemist has to develop a field between those of the pure chemist and the mechanical engineer. His technical training should be designed to give a thorough knowledge of the fundamentals of chemistry with particular emphasis on inorg. chemistry. In addition he requires instruction in structural and mechanical engineering. J. S. Laird (*C. A.*)

18. Cornish stones of England, Anon. *Tonind.-Ztg.*, **45**, 442 (1921).—Cornish stone is a natural mixt. of feldspar and quartz together with kaolin fluorspar, muscovite and topaz. It is often found in the same bed with China clay. It contains albite or albite-oligoclase as well as orthoclase. There are many different varieties of Cornish stone varying from hard purple, to mild purple, dry white and buff stone. The softer varieties show a higher degree of kaolinization. Typical analyses are as follows:

	Hard purple	Buff (Cornish)	Dry white
SiO_2	72.28	73.18	73.96
Al_2O_3	14.90	16.13	15.90
Fe_2O_3	0.50	0.52	1.40
MnO	0.01	0.02	—
CaO	1.66	0.61	1.89
MgO	0.15	0.14	0.32
K_2O	5.25	4.41	4.34
Na_2O	3.01	2.18	0.45
H_2O	0.81	2.01	1.11
P_2O_5	0.53	0.45	—
F	0.88	0.23	—
Cl	0.02	—	—
TiO_2	0.05	0.06	—
Li_2O	0.02	0.02	—

	Kaolin	Feldspar	Quartz
Purple stone	6.7	77.2	16.1
Buff stone	14.6	55.5	30.9

H. G. Schurecht

Geology

19. **Automatic method for mechanical soil [and clay] analysis and ways of recording it.** SVEN ODÉN. *Bull. Geol. Inst. Univ. Upsala,* **16,** 15–64 (1919); cf. *C. A.* **13,** 1198 (1919).—Exact mechanical soil analysis is difficult because of the dependence on temp. and uniformity of sample. It is measured through the behavior of particles of soil falling in a liquid. Theoretically the velocity of particles may be expressed as $V = Cr^2$ (Stokes law), where C is a const. equal to $(^2/_9)g[(\sigma - \sigma_1)/\mu]$, where g is the const. of gravitation, σ the sp. gr. of the particles and σ_1 that of the liquid and μ the size of particle. This equation is based upon the supposition that the size of particles does not exceed a certain critical radius (85μ for quartz). As particles usually have different forms it is necessary to introduce a radius of equivalence for particles. The medium radius of equivalence for a certain amount of soil should then be equal to the medium size of particles in suspension. If medium sp. gr. of soil be placed at 2.7 and μ be given as 0.0114 at 15° in abs. measure, the const. C in an aq. suspension should equal $5.546.10^{-3}$. This const. will vary with μ which again varies very much with temp. If a substance varying in size is suspended in a liquid: (1) Velocity of accumulation is proportional to the total amt. of the substance and reciprocally proportional to the height of the liquid, but independent of time. (2) If v_i is the velocity of particles of size i then an equal amt. each of particles of smaller size will sink down in the time interval O to h/v_i. For carrying out expts. O. used a glass cylinder 35 cm. high and 138 mm. inside diam. filled with water. Inside of this and near the bottom a gold-plated silver plate is hung up by strings in the water. The substance to be analyzed is let in on top of the cylinder and a certain amt. is collected on to the plate, which again is connected with an automatic balance. When this balance is upset an elec. current closes releasing small steel shot, which again equal the wt. of collecting particles on the scale. The steel shots have to be uniform and are chosen in 4 sizes weighing, resp., 0.4366 g., 0.1276 g., 0.0544 g., 0.0133 g. Velocity of accumulation is thus closely detd. and recorded on a recording app. attached to the balance. After expts. are made and recorded the number of particles is counted with the ultra-microscope after the method of Zsigmondy-Siedentopf. A falling curve may be shown in a diagram with the amts. of particles $g\ (r)$ as ordinates and the radii of equivalence r as abscissas. Graphically this may be shown by the integration of a function $F(r)$ between r_1 and r_2:

$$g(r_1) - g(r_2) = \int_{r_2} (dq/dr)dr = \int_{r_1}^{r} F(r)dr.$$

$F(r)$ represents here the curve of distribution of the particles and this may be calcd. from the above formula. Sometimes particles will coagulate, the falling curve then differing slightly from the ordinary one. The curve of distribution is calcd. and shown in a diagram, where ordinates and abscissas are represented, resp., by the logarithms of dP/dt and of $t(P = \text{weight of par-}$

ticles). N is number of particles and being a function of r_1 $N(r)$ is called function of frequency. Tables and diagrams show results obtained with Danish Rhaet Ler and mica-clay from Venid. Three photographs are given of cylinder, automatic balance and recording app., resp. **Preliminary treatment of soil in mechanical analysis.** *Ibid.*, 125–34.—In different soils individual particles are often combined into aggregates differing from the primary particles. In preliminary treatments, such aggregates are broken up, all particles being reduced to primary ones. Normal method for treatment: The material is brushed with a stiff brush when in distd. water; then the larger particles are removed in a centrifuge and the material is brushed again. Enough NH_3 is added to give a 0.01 N soln. and the whole is mixed in a machine for 24 hrs. NH_3 breaks up aggregates especially well for soils containing Ca salts, NaCl, KCl and $MgCl_2$. Boiling breaks up aggregates also but produces coagulation afterwards; it is therefore not advizable to boil.

G. N. KIRSEBOM (*C. A.*)

20. Clay of Ancylus. SVEN ODÉN AND A. REUTERSKIOLD. *Bull. Geol. Inst. Univ. Upsala*, **16**, 135–58(1919).—Expts. were carried out on this clay according to methods given by Odén (preceding abstract). The clay of Ancylus was geologically detd. as Post-Glacial sweet-water sediment formed in the intermediary period, when the Baltic Sea was shut out from the Atlantic, forming the Ancylus lake, so-called after the mollusk *Ancylus fluviatilis* found in the sediment. Mechanical analysis detd. the size of particles to be between 0.17 and 7.0μ. Chemically the particles differ in compn. according to size, the larger ones being richer in silica. Samples were dissolved in strong HCl to find the action on the particles. Results are given of different size fractions before and after treatment with acid, av. size of articles and their number being detd. Fractions taken were $<0.23\mu$, 0.23–0.60μ, 0.60–1.05μ and 1.05–5.13μ. In the original sample 33.5% was undissolved. Action of acid was strongest on the fraction around 0.4μ. Av. size of particles increased in smaller fractions but decreased in larger ones. Tables show results of mechanical tests and a graphic table indicates the influence of HCl on chem. compn.

G. N. KIRSEBOM (*C. A.*)

Refractories and Furnaces

21. Unfired refractory brick. P. SCHNEIDER. *Tonind.-Ztg.*, **45**, 452–454(1921).—The properties of silica brick made in a manner similar to sand-lime brick were studied. The brick were built into the furnaces in the unfired state. The results are summarized in the following tables.

	Compression strength kg. /cm.²					Volume shrinkage	
No.	Raw	Hardened	650°C	Cone 10	Cone 14	Cone 10	Cone 14
1	very weak	149	38	115	280	+0.8	± 0.
2	10	40	36.3	95	360	+1.1	+ 1.9
3	8	51.5	36	92	350	+1.3	+ 2.24
4	10	180	68	132	210	+0.5	+ 1.76

TABLE (*Continued*)

No.	Raw	Hardened	650°C.	Cone 10	Cone 14	Cone 10	Cone 14
5	12	165	74	140	240	+0.5	+ 1.80
6	15	78	53.5	150	170	+0.8	+ 1.0
7	20	128	59.2	180	300	—1.0	—12.0
8	18	121.5	59.0	175	310	±0.	—12.0

	Density			% absorption			
No.	Raw	Cone 10	Cone 14	Raw	Cone 10	Cone 14	Softening point
1	1.79	1.77	1.68	15.0	15.5	15.2	26
2	1.97	1.93	1.88	9.1	12.2	12.3	34–35
3	2.03	1.96	1.84	10.0	11.5	10.4	34–35
4	2.03	1.96	1.84	9.5	11.8	14.0	33
5	2.00	1.89	1.81	9.7	13.0	14.1	33
6	1.92	1.82	1.8	12.8	15.2	15.7	31
7	1.76	1.73	2.83	14.4	17.3	6.8	17
8	1.79	1.73	2.02	15.9	17.4	4.2	17

Samples 2, 3 and 4 have compositions similar to silica brick. 4 and 5 contain an increased CaO content which decreases the refractoriness. 6 contains clay together with CaO. Clay retards the cementing action preventing to some extent the formation of calcium hydro-silicates. Samples 7 and 8 contain fire-clay grog as was specified in the patent of Gürtler. The grog decreases the refractoriness too much. H. G. SCHURECHT

22. Sintering of dolomite. F. I. *Tonind.-Ztg.*, **45**, 442(1921).—Dolomite containing 4% $Al_2O_3 + Fe_2O_3$ can be sintered most easily. The raw dolomite is mixed with coke and the mixt. calcined at 1100°–1280°C. The calcined material is crushed and used in the granular form for furnace linings. It is also made into brick with 5–8% tar as a binder and pressed when hot under a high pressure. H. G. SCHURECHT

23. Uniform high temperature throughout a large volume. E. F. NORTHRUPP. Ajax Electrothermic Corporation. Trenton, N. J. *J. Ind. Eng. Chem.*, **13**, 639(1921).—A description of an Ajax-Northrup high frequency furnace for securing and maintaining a uniform temp. up to 2500°C throughout a graphite chamber (of ½ to 1 cu. ft. vol.) packed in lamp black.

24. Judging sands for foundry use. I. HENRY B. HANLEY AND HERBERT R. SIMONDS. *Foundry*, **48**, 741–6(1920).—Foundry sands may be classified broadly as follows: (1) Moulding sand; (2) core sand; (3) racing sand; (4) fire sand; (5) gravel; (6) high-SiO_2 steel molding sand; and (7) parting sand. (1) is usually a mixt. of quartz, feldspar, and clay, having peculiar properties or holding a bond when "tempered" with a small amt. of H_2O. The term often covers (3) also, the difference in the two being merely one of refinement in the bond property. When refinement of finish is necessary, a specially fine-grained sand is necessary. (2) usually is a straight SiO_2 sand, sometimes carrying 10–35% feldspar. Cohesion is obtained by an organic binder, such

as linseed oil, molasses, dextrin, resin, etc., or a pitch compd. (4) is usually a coarse SiO_2 sand, with only small quantities if any of clay or feldspar. In the foundry it is mixed with fire-clay to make cupola and ladle linings. (5) is a coarse SiO_2 sand combined with clay to make possible its use as a molding sand. Its function is to increase the porosity of a mold. As castings approach the ton size, porosity of the sand in the mold becomes of great importance. (6) is pure quartz and runs from coarse to fine grades. It must be very infusible and is always artificially bonded. (7) is a pulverized fine quartz sand usually of a fineness to pass a 100-mesh sieve. A table is given showing chem. analyses of the different typical sands, and another table shows the results of sieve tests. Analytical methods for detg. SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, and K_2O are given. The refractoriness conferred by the SiO_2 in a sand depends upon whether it is present as such or as a constituent of feldspar. The Fe_2O_3 content often gives a good indication of the amt. of bond in the sand; it may run from 3.5 to 15% in a molding sand. A chem. analysis does not in any way indicate the phys. properties of a molding sand, and, since these properties are the most important, chem. analysis should be supplemented by a mechanical analysis where possible. It commonly consists of a sieve test. In addition, a so-called rational analysis is made to obtain information on the relative amts. of the principal mineral constituents—quartz, feldspar, and clay substance. Sands high in feldspar fuse more readily than those of low content. The quartz content of a good refractory molding sand does not run below 90%. The method of detg. clay substance is one of soln. of sol. material in reagents, and not only the hydrated Al silicate (clay) but other sol. silicates are reported as clay substance. Hence this detn. must be used with care.

The method is as follows: 1 g. of dry, finely ground molding sand is weighed into a 150-cc. beaker and 15 cc. concd. H_2SO_4 are added. The mixt. is stirred well and allowed to digest for 12 hrs. at a temp. high enough to give off acid fumes. The soln. is cooled, dild. with 100 cc. of 10% NaOH soln., filtered through a Gooch crucible and washed with about 50 cc. of 25% HCl. The residue is washed with hot H_2O until free from chloride; it consists of the quartz and feldspar. It is ignited to const. wt. and the clay substance assumed to be equal to the wt. loss over the original sample. The residue is then subjected to an alk. fusion (5 parts of Na_2CO_3) and the SiO_2 removed in the usual way. The filtrate is neutralized with NH_4OH, boiled for a few moments, and filtered. The ppt. is washed with hot H_2O containing a few drops of NH_4OH, then dried and ignited. It is taken as the Al_2O_3 content of the sample. It is calcd. to feldspar by assuming the latter to contain 18.34% Al_2O_3. The amt. of quartz is closely indicated by the difference between the feldspar and the clay, detd. as described above. A more reliable method of detg. the bond is known as the bond absorption test. It consists in detg. the amt. of dye absorbed by the colloidal matter present. The amt. of colloidal matter divided by the surface area of the sand gives the bond "density," which furnishes a much more reliable guide to relative bond strength than any other single quantity. An additional point to consider irrespective of surface area

is grain shape and amt. of voids. The effect of this factor can be detd. to some extent by experience, although the sieve-test data may be used to obtain approx. results. Evenly graduated amts. remaining on the different sieves indicate a low void. The bond absorption test is carried out as follows: 25 g. of the prepd. molding sand are placed in a 500 cc. wide-mouth bottle, and 250 cc. of distd. H_2O are added, together with 5 cc. of 10% NH_4OH. The bottle is sealed with a glass stopper and paraffin wax and rotated for 1 hr. Then 140 cc. of H_2O are added and the soln. is acidified with about 5 cc. of 10% acetic acid. Sufficient dye (crystal violet) is then added to insure a slight excess after complete absorption. The bottle is again sealed and agitated for 2 hrs. The bottle is removed from the machine and allowed to stand for a few hrs. until the coarser particles have settled to the bottom. From the top portion of the liquid 100 cc. are withdrawn and to this portion are added 25 cc. of H_2O and 2 cc. of 10% acetic acid. A 5-g. skein of mordanted cotton yarn is introduced into the liquid and the temp. gradually raised through a period of 40 mins. to 60°, by which time, through careful movement of the skein, all the dye should be removed from the soln. The skein is removed, washed, and dried at 75° and comparison of its color made against a standard set of skeins, the amt. of dye which was not absorbed by the colloidal matter being thus detd. Usually the standard skeins are made by depositing on each of 6 skeins 6, 8, 10, 12, 14 and 16 mg. of crystal violet dye. As a further indication of the bonding value of sands, a transverse strength test is often made. To make this test, 400 g. of molding sand are "tempered" with H_2O up to the point of satn. It is then rammed into a cement briquet mold, having a 1 x 1 in. cross-section at the center. After removal from the mold the specimen is dried over night and then held for 3 hrs. at 100° in an oven. It is tested in a suitable transverse testing machine, with a breaking capacity of from 1 to 150 lbs. per sq. in. A simple easily constructed machine is described. Photographs of 8 typical sands (8 magnifications) are shown. A. L. FEILD (*C. A.*)

25. The coking plant of the Rhenish steel works in Duisburg-Meiderich and the use of silica brick for coke ovens. J. ENGENAUER. *Stahl u. Eisen*, 40, 1326–35 (1920). CARLE R. HAYWARD (*C. A.*)

26. Standardization of burning. J. H. KRUSON. *Brick and Clay Record*, 59, 106–110 (1921).—Due to sluggish draft during water-smoking the time of firing ware in periodic kilns is too long and hence expensive. It is possible to remove all of the mechanical H_2O from clays by drying but the ware would be too hot to handle. The H_2O in the kiln atmosphere comes from the fuel as well as from the clay. Coke and hard coal contain 1–3% H_2O; soft coal 3–15%; lignite or brown coal 14–40%; and wood 15–30%. Gas and oil contain but little moisture. The proper draining of the kiln bottom is essential since damp floors and flues mean that more moisture must be evaporated and carried away. Many manufacturers insist on 8–10 burns which is longer than necessary. The continuous kilns have proved that clays can be successfully fired in 120–132 hrs. or less. Rapid firing in some periodic kilns is impossible

because of faulty construction. Ample flue and grate space should be provided to allow a more rapid increase in temp. during water-smoking. By increasing the draft during water-smoking in a periodic kiln the time of firing was reduced from 192 hrs. to 120 hrs. with a saving of 0.18 tons of coal per ton of ware and with an accompanying saving in labor and increased kiln capacity of over 20%. H. G. SCHURECHT

27. **Industrial application of powdered fuel.** JAS. P. SHAGDEN. *Iron Age,* **107,** 839–42 (1921).—Cf. *C. A.*, **14,** 1028, 3306.—S. discusses the theory of transfer of heat energy and the temp. cycles involved, the design of combustion chambers, and briefly enumerates the processes peculiarly suited to powdered fuel. He advizes against too great optimism in setting up the process without a careful study of conditions involved. J. L. WILEY (*C. A.*)

PATENTS

28. **Highly refractory article and method of producing the same.** HENRY H. BUCKMAN AND GEORGE A. PRICHARD. U. S. 1,375,077, April 19, 1921. In the manufacture of a refractory composition, or material, the step consists in incorporating zircon into the batch.

29. **Manufacture of refractory and insulating products.** GEORGES LOUIS DIMITRI AND JULES EDOUARD DELAUNAY. Paris, France. 1,374,493, April 12, 1921. A process of manufacturing refractory and insulating products, comprising mixing together ceramic materials in a powdered state, and moulding the powdered mixture under pressure in a vacuum into the form of articles of definite shape.

30. **Kiln and fire-brick therefor.** SIMON HENRY HARRISON. U. S. 1,374,203, April 12, 1921. An iron-incased brick-lined calcining chamber or furnace, which consists in wedge shaped bricks having the area of contact between the lining brick and the inclosing casing reduced to flanges only, the structure being sealed against passages of gases longitudinally of the casing and the bricks being held in position by their mutual wedging actions.

C. M. SAEGER, JR.

31. **Refractory substances.** A. ROLLASON. Brit. 156, 447, April 21, 1920. A refractory material for lining furnaces is made by roasting at about 1800° magnesite or dolomite in granular form with 5–10% of basic slag in an internally fired rotary kiln having a basic lining. From the kiln the material passes into an annealing chamber, where it is allowed to cool slowly.

(*C. A.*)

32. **Cooling means for tunnel-kilns.** JOHN B. OWENS. U. S. 1,379,714, May 31, 1921. A tunnel kiln having a furnace for delivering heat into the interior of its tunnel and provided with a sealed cooling zone whose side walls are provided with air circulating spaces sealed from the interior of the cooling zone, the spaces being adapted to receive outer air at their lower parts, and to void the air at their upper parts, and being arranged and adapted for the upward passage of the outer air for the purpose of cooling in the inner tunnel walls and taking off the heat radiated from the ware within the cooling zone without direct entry of air into the cooling zone or direct exit of air therefrom.

33. **Combustion-chamber for tunnel-kilns.** JOHN B. OWENS AND ELLSWORTH P. OGDEN. U. S. 1,378,190. May 17, 1921. A tunnel kiln having a combination chamber at its side, a baffle for the upper part of the combustion chamber where the latter faces the interior of the tunnel, and piers supporting the baffle, the piers being separated by discharge ports or passages through which the heat and products of combustion pass from the combustion chamber to the interior of the tunnel, the baffle being provided with ports which open into the interior of the tunnel at the lower portion of the baffle and communicate with the combustion chamber in the upper portion thereof.

34. **Method and apparatus for melting oxids, etc., without contamination.** EDWIN FITCH NORTHRUPP. U. S. 1,378,189. May 17, 1921. In the melting of metallic oxids and like chemicals the combination of a crucible composed of a metallic oxid having a melting point in excess of the intended temperature of the melt and a molten body of the metal whose oxid is being treated within the bottom of the crucible.

35. **Lining for kilns.** ALBERT FRITZ MEYERHOFER. Mannheim, Germany. 1,378,710, May 17, 1921. A lining for the purposes set forth which consists of an inner layer containing a high percentage of corundum combined with an insulating layer of porous brick.

36. **Means for cooling tunnel-kilns.** JOHN B. OWENS. U. S. 1,377,522, May 10, 1921. A tunnel kiln provided with air circulating flues or ducts extending lengthwise within its walls opposite the space below the platform of the ware conveying means.

37. **Method of making clay and graphite crucibles.** JEAN HUBERT LOUIS DE BATS. U. S. 1,374,910, April 19, 1921. The method of making crucibles or pots containing clay, which consists in mixing metal of the aluminum-magnesium group in a finely divided form with the material from which the crucible or pot is formed, and molding the same, whereby the crucibles or pots may be burned shortly after molding. C. M. SAEGER, JR.

38. **Calcining furnaces.** A. V. GOWEN-LECESNE. Brit. 148, 497, July 10, 1920 The pat. relates to the manuf. of refractory or abrasive products from siliceous rocks, refractory clays, MgO, dolomite, chrome iron, spinel, agglomerated powders of emery and corundum, and Zr and Ce earths, and comprizes forms of furnace adapted for the complete calcination of the raw materials. A suitable construction is specified. (*C. A.*)

39. **Furnaces; cooling.** A. BIGOT. Brit. 152,602, Oct. 8, 1920. An app. for calcining, baking, etc., applicable also for cooling materials, comprizes a heat-insulated chamber having hollow walls loosely packed with masses of heat-absorbing material, such as bricks, through which, as also through the chamber itself, hot (or cold) gases are caused to flow. The invention is applicable for *drying clays*, etc., *dehydrating gypsum*, etc., *treating $NaHCO_3$ and silica-limestones*, and *baking br ad.* (*C. A.*)

White Ware

40. The cause and control of lead poisoning. WILBER S. SLEMMONS. *Mining Sci. Press,* **122,** 427–8 (1921).—Physiol. action is described. An app. is shown for testing the amt. of Pb in the air of industrial plants. Individuals may develop acute plumbism when working in air containing 0.1 mg. of Pb per cu. ft. A preventive is a proper ventilating system. A. H. HELLER (*C. A.*)

Brick and Tile

PATENTS

41. Brickmaking apparatus. PEYTAN ANDREWS. U. S. 1,374,173, April 12, 1921.—An apparatus with the agitating and feeding vat into which the mixture is deposited, a tunnelway having a throat connected with the vat, with a plunger for forcing the material through the tunnelway, a plate feeding mechanism for delivering separating plates to the tunnelway on the recession of the plunger; means for reciprocating the plunger.

42. Artificial stone or brick. WOOTSON L. SANDERSON. U. S.1 ,376,464, May 3, 1921. Artificial stone including, in approximately the proportions stated, 5 cubic feet of sand, 3 $^3/_4$ pounds of red oxid of iron, 2 $^1/_2$ pounds plaster of Paris, 1$^1/_4$ pounds of ocher, 1$^1/_4$ pounds of salt, 10 ounces of sugar, and 95 pounds of cement.

43. Brick-kiln. FRANK MUNHOLLON. U. S. 1,375,719, April 26, 1921. A brick kiln having a series of furnaces spaced about the outer wall thereof, a floor having substantially uniform space therein, transverse passages beneath the floor, and passages connecting these transverse passages with furnaces, and having openings into the transverse passages varied in size with relation to the distance from the furnaces. C. M. SAEGER, JR.

Glass

44. The repair of crystallized glass apparatus. HERBERT BAILEY. *J. Am. Chem. Soc.,* **43,** 1319 (1920).—If an asbestos paper soaked with salt solution be held in the flame in such a position that the sodium vapors envelope the devitrified glass the crystallization will usually disappear by the time that the glass is soft enough to work. ED.

45. The use of acetylene in glass blowing. A. S. COOLIDGE. *J. Am. Chem. Soc.,* **43,** 1319 (1921).—An ordinary glass-blower's torch fed with acety lene and compressed air gives a flame in which Pyrex glass can be worked rapidly and easily. ED.

46. Bottle manufacture in Spain. ANON. *Le Verre,* **1,** 133–35 (1921). ED.

47. The world crisis in the glass industry. ANON. *Le Verre,* **1,** 137–8. —A description and comparison of industrial conditions in Belgium, France, England, Germany, Italy and the U. S. ED.

48. Silica glass. G. FLUSIN. *Chimie & industrie*, 3, 729–49 (1920).—In this article complex relations existing among the various forms of silica, cryst. and amorphous, are discussed in detail. Amorphous silica is the form stable at high temps., quartz being converted to silica glass by rapidly-heating above 1470°, tridymite at 1670° and crystobalite at 1625–1710°. Silica glass on being heated for some time at 1500° devitrifies, owing to recrystn. to crystobalite. Conversion to tridymite is brought about by heating to 900–1470° in the presence of KCl. Fused quartz is very viscous even at temps. well above its melting point, It begins to volatilize rapidly at 1750°, while it is still pasty, so that it is very difficult to obtain silica glass free from bubbles. The following physical properties of silica glass are given: d. 2.21, coeff. of expansion 49×10^{-8}, sp. heat 0.20–0.28, heat of fusion (by calcn.) 64–6 g. calories per g. It is transparent down to $\lambda=0.220\ \mu$; n_D 1.4585, dispersion 0.0068, resistivity at 15–150°, 2×10^{8} megohms per cm., at 800°, 20 megohms, modulus of elasticity 6.6 kg. per mm.[2] Silica glass is permeable to gases especially to H and at high temps. It is not appreciably sol. in water even at 100°, nor in strong acids except hydrofluoric and phosphoric. It is not attacked by salt solns. but is appreciably sol. in alkalies, especially when hot. It reacts with metallic oxides as CuO when heated to 900°. J. S. LAIRD (*C. A.*)

49. Glass paper. RASSER. *Kunstoffe*, 10, 121–2, 139–40 (1920).—A general description of the manuf. C. J. WEST (*C. A.*)

50. A new principle in blow pipe construction. H. G. BECKER. Royal Dublin Society. *Nature*, June 2, 1921, p. 446. The essential features of a quick change blow-pipe operating at constant air pressure are discussed and the necessity of different bores for the different flames is emphasized. The tubular shape common to all hitherto existing blow pipes is shown to be unnecessarily cumbersome, and is therefore abandoned. A form of blow-pipe giving a great range of flames (including a flat blow-pipe flame) each provided with an air jet of suitable size and allowing of instantaneous change was described and exhibited in operation. WM. M. CLARK

PATENTS

51. Frosted glass. T. UEDA OF KYTO. Brit. 144,739, 1919. *Science Abstracts.*, Sec. B., April 29, 1921, p. 177. By coating glass with alkali silicates, basic lead silicates or lead salts which when heated react with the glass to form a product decomposable with hydrochloric, sulphuric or nitric, as well as hydrofluoric acids, a frosted surface is obtained.

WM. M. CLARK

52. Glass furnaces. HARVEY GAS FURNACE CO., LTD. E. W. HARVEY. Brit. 162,232. Ill. Off. Jour. Pats., June 15, 1921, p. 2347. In a gas fired melting furnace for glass heated by one or more reversible flames, supplementary ports are provided near the gathering holes through which a portion of the heating gases is drawn, under the control of dampers, by a draught stronger than that serving the main ports. These may be connected directly to the chimney or through regulators. WM. M. CLARK

53. Glass manufacture. M. Meunier. Brit. 162,193. May 8, 1920. Ill. Off. Jour. Pats., June 15, 1921, pp. 2334–6. Describes, with four drawings, the mechanical details of a glass blowing machine; for making hollow glass articles, particularly those, such as siphons, which must withstand internal pressure. It is of the type in which the article during formation is carried by a table, rotating intermittently, to the mechanisms for performing the various operations of blowing. Wm. M. Clark

54. Glass manufacture. A. A. Kelley and B. D. Jones. London, Brit. 160,495. Nov. 20, 1919. Ill. Off. Jour. Pats, May 19, 1921, p. 1723. In the manufacture of glass, vitreous enamels and glazes sodium pentaborate is substituted for borax or boric acid and the necessary adjustment of the alkali content is made in any suitable manner. Wm. M. Clark

55. Glass. W. G. Clark. N. Y. City and L. N. Burner, Locarno, Switzerland. Brit. 161,192. Ill. Off. Jour. Pats. May 25, 1921, p. 1978. To fine molten glass extra heat is supplied by passing an electric current thru the melt, preferably A. C. current of 60 cycles or higher. The necessary apparatus is described and sketched. Wm. M. Clark

56. Glass-grinding machine. Edward A. Ryon. U. S. 1,373,835, April 5, 1921. A glass grinding machine comprising a grinding wheel, a driving shaft, a pulley thereon, a clutch for coupling the pulley to the shaft, a spindle, a ratchet and pawl connection between the shaft and the spindle for rotatively advancing the spindle step by step, and annular cam on the driving shaft, and a rocking lever actuated by the annular cam to move the spindle toward and from the cutting wheel.

57. Glass-severing. Karl E. Peiler. U. S. 1,379,594. May 24, 1921. In a machine having reciprocatory shear blades for cutting molten glass, mechanism for independently tilting each of the shear blades downward while they are cutting.

58. Method of ornamenting sheet-glass. Michael J. Howard. U. S. 1,375,251, April 19, 1921. This method comprises placing colors on the surface of a liquid, dipping an object into the liquid to cause the colors to be applied to the surface of the object and also to be removed from the liquid, removing the object from the liquid, then applying a coating to the colored surface of the object, and then separating the surface of the liquid which has the colors removed, from the remainder of the surface.

59. Glass-working machine. Frank L. O. Wadsworth. U. S. 1,375,336, April 19, 1921. An apparatus for cutting streams of viscous materials comprising a pair of cup-shaped mating members one having a cutting edge capable of entering the stream and the other having a projecting cutter capable of entering the stream overlapable upon the first-mentioned cup.

60. Process for making articles of quartz glass. John Scharl. U. S. 1,375,657, April 19, 1921. The process of making articles of quartz glass consisting in heating the quartz into a plastic mass in an electric resistance furnace about a resistance core, closing the bottom of the fused mass, then removing the same from the furnace together with the hot core and blowing the mass out into desired shape.

61. **Glass-drawing apparatus.** JOHN J. BLOXSOM AND ELMER E. MYERS. U. S. 1,375,818, April 26, 1921. An apparatus for drawing glass cylinders, with a turn table provided with a molten glass container, an air conduit extending through the table and container, a verticle disposed air supply pipe below the table provided with a bottom discharge opening, the top of the pipe being adapted to register with the bottom of the conduit when the glass container is in drawing position, a closure for the discharge opening, and means coördinated with the movement of the table for opening the closure to permit the discharge of broken glass from the air supply pipe.

62. **Glass-tank.** ARTHUR E. SPINASSE. U. S. 1,375,941, April 26, 1921. A glass drawing tank, with floating drawing ring, a flange projecting up from the top of the drawing ring, and a water-cooled ring-holding means adapted to engage the ring on its top without the flange to hold it in drawing position while the flange protects the glass within the ring from the chilling effect of the water-cooled ring-holder device.

63. **Method of and apparatus for cutting sheet-glass.** JOSEPH P. CROWLEY. U. S. 1,377,320, May, 10, 1921. A glass cutting apparatus with a device for scoring a sheet of glass. A method of cracking glass, which consists in extending a score along the surface thereof, and concomitantly applying a series of taps or blows progressively along the score at a substantially constant distance from the point to which the score has been extended, thereby progressively cracking the glass along the score.

64. **Glazing system.** ALFRED ERNST DROWN. England. 1,377,673, May 10, 1921. A reinforced glazing bar, and glass sheets supported thereon, with means for forming a fixed part of the bar and secured to the reinforced member thereon to retain the glass sheets in position.

65. **Process and apparatus for severing sheet-glass.** HARRY G. SLINGLUFF. U. S. 1,373,533, April 5, 1921. A process of severing a continuously formed sheet of glass which consists in applying a pair of electrically heated transversely extended members to the opposite sides of the sheet at the same time.

66. **Machine for the automatic and continuous manufacture of glass bottles.** GEORGE ORLANDO TAGUE. England. 1,373,272, March 29, 1921. A machine for the manufacture of glassware, with a mold charging and forming device and a separate blowing device, with intermediate transfer device having an article carrying means comprising opposing gripping members movable up and down, and means for actuating the gripping members having an up and down movement independently of the corresponding movement of the gripping members whereby an article carried by one of the first mentioned devices is engaged and an article at the opposite side is simultaneously disengaged for deposit upon the other of first mentioned devices.

67. **Method of finishing glass.** LEE SHOWERS. U. S. 1,373,532, April 5, 1921. The method of finishing smoothed relatively opaque glass which consists in employing members with a polishing powder approximating in color that of the glass and maintaining the members at a degree of drying such as will cause a burning of the glass.

68. Device for severing glass. HARRY F. HITNER. U. S. 1,373,728, April 5, 1921. A glass cracking off device, a heating chamber, a flexible cracking off member mounted for movement into and out of the chamber, and with means for heating the chamber.

69. Glass-delivering apparatus. KARL E. PEILER. U. S. 1,373,202, March 29, 1921. An apparatus with means for feeding molten glass with number of sets of receptacles; a movable chute having an inclined glass conducting surface, and automatic device actuated in predetermined order and time for moving the chute to bring the same inclined conducting surface successively into delivering alignment to the receptacles of the different sets.

70. Glass-grinding machine. EDWARD A. RYON. U. S. 1,373,836, April 5, 1921. A glass grinding machine comprising a work holder, with a mechanical movement producing an oscillatory adjustment of the work holder, with means for reciprocating the work holder between each oscillatory adjustment thereof, device for rotatively adjusting the work about an axis at right angles to the axis of oscillation, and means for reciprocating the spindle.

71. Machine for rolling plate-glass. HARRY A. REYNOLDS. U. S. 1,375,014, April 19, 1921. A glass mechanism having a table, a roll mounted on the table for movement longitudinally thereof, a pair of roller members extending transversely on the table at its end and adapted to receive the roll and support it for rotation out of contact with the table, whereby the roll is turned while in such position. C. M. SAEGER, JR.

Enamels

72. The penetration of iron by hydrogen. (Possible relation to fish scaling.) T. S. FULLER. *Gen. Elec. Rev.*, **23**, 702–711 (1920).—The penetration of H into iron was found to be as high when exposed to 1% sulphuric acid solution as when made the cathode during an electrolysis with a similar solution. At 20°C, 2 cc. of H penetrated a seamless iron tube, 12″ long x $^{11}/_{16}$″ outside diameter and $^{1}/_{16}$″ wall, during 48 hrs. Passage of H through iron is apparently facilitated by the presence of a coating of tin and retarded by one of zinc or copper. 1% potassium bichromate added to sulphuric acid prevents the passage of H through iron for at least 96 hrs. ED.

Cement, Lime and Plaster

73. A new type of automatic cement tester. T. Y. OLSEN. *Proc. Am. Soc. for Testing Materials*, **20**, II, 408–10 (1920).—The app. is similar in a no. of respects to the ordinary shot machine. The load is applied by a lever carrying a heavy weight. When not in use, this lever is supported at one end by a column of liquid confined in a vertical cylinder. When a briquet is in position, the lever is set in motion by turning a thumb screw, which allows the oil to float from the cylinder, and the load is applied at the rate of 600 pounds per min. J. C. WITT (*C. A.*)

74. Report of Committee C-11 on gypsum. WARREN E. EMLEY, *et al.* *Proc. Am. Soc. for Testing Materials*, **20**, I, 380–6 (1920).—The report includes recommendations of the committee on revisions of specifications as follows:

Tentative specifications for gypsum, tentative specifications for calcined gypsum, tentative methods for tests of gypsum and gypsum products, and specifications for gypsum plasters. In the tentative methods for tests of gypsum and gypsum products are considered the temp. of drying, the size of screen used for fineness detn., the chem. detn. of SiO_2 and MgO, the method of calcg. results, the detn. of normal consistency by means of the Southard viscosimeter, water-carrying capacity, dry bulk, wet bulk, time of setting, tensile strength and compressive strength. J. C. Witt (*C. A.*)

75. Tentative methods for tests of gypsum and gypsum products. Anon. *Proc. Am. Soc. for Testing Materials,* **20**, I, 634–46 (1920).—The tests considered are free H_2O in gypsum, fineness, chem. analysis of gypsum and calcined gypsum, microscopic examn. of gypsum and calcined gypsum, precaution for physical tests, normal consistency of calcined gypsum, water-carrying capacity, detn. of dry bulk, detn. of wet bulk, time of setting, tensile strength, compressive strength, and sand-carrying capacity of calcined gypsum. The methods for chem. analysis include prepn. of sample, detn. of combined H_2O, CO_2, SiO_2, Fe_2O_3, Al_2O_3, CaO, MgO, SO_3 and Cl and directions for calcg. results. J. C. Witt (*C. A.*)

76. Plastic gypsum plaster. Warren E. Emley. *Chem. Met. Eng.*, **24**, 740–1 (1921).—Advance description of a method of prepg. gypsum plaster to obviate the necessity of adding lime to increase its plasticity; the patent when issued is to be for free public use in the U.S.A. The method consists in fine grinding the calcined gypsum in a ball or tube mill, at the same time *preventing* the escape of water, so that the product leaving the mill contains 9 parts by wt. H_2O to 136 parts $CaSO_4$, or about 6.2% H_2O. "If the grinding is sufficient to liberate all of the water [*i. e.*, with air passing through the mill] the resultant product is sol. anhydrite. This is a peculiar form of anhydrous $CaSO_4$ and differs from the mineral anhydrite in its great affinity for water—a very short exposure to moist air is sufficient to change it back to the hemi-hydrate. When calcined gypsum is subjected to grinding under such circumstances that water is not permitted to escape from the system, an entirely new product results. No satisfactory explanation has yet been evolved but the fact remains that the product is plastic. Up to a certain limit, the degree of plasticity seems to depend upon the duration and speed of grinding. Jerome Alexander (*C. A.*)

77. Lime-mortars: Solution and conversion of solid substances into colloids. V. Kohlschütter and G. Walther. *Z. Elektrochem.*, **25**, 159–83 (1919).—The rate at which CaO, prepd. from $CaCO_3$, $Ca(OH)_2$, and Ca oxalate, resp., combines with water vapor at the ordinary temp. has been detd. The vol. changes and the amt. of water taken up have also been detd. The rate of absorption is shown to differ with the various samples of CaO. Further, the rate of sedimentation of $Ca(OH)_2$ has been measured for $Ca(OH)_2$ prepd. by slaking lime in water or solns. of $CaCl_2$, $Ca(NO_3)_2$, NaCl, KCl, KNO_3, NaOH, AcONa, KCNS, NH_3, NH_4 oxalate, and Na carbonate of various concns. (*C. A.*)

78. Some new features in lime kiln construction. RICHARD K. MEADE. *J. Ind. Eng. Chem.*, **13**, 722–27 (1921).—**Heat losses.** An analysis of the various sources of heat losses is given. These amt. to about 60% even in good practice.

The flame kiln. An oval *cross sec.* above fire box with two sides drawn in slightly is preferred. The *ht. of shaft* should be as great as draft conditions will permit. A quick acting tight fitting *charging arrangement* should be used. A stone *charging bin* at the top of the shaft should be employed. A steel *cooling cone* is recommended for coal fired kilns. For gas fired kilns the heat from the cooling lime should be used to preheat the air used for combustion. A *quick acting draw* on the cooling cone is described. It cuts down to a min. the excess air entering the kiln during drawing. A *hand stoker* increases greatly the capacity of the kiln, cuts in half the labor of stoking, reduces fuel consumption, and eliminates the core. A layer of sil-o-cel between the shell and the brick reduces radiation losses. Concrete *shells* and concrete *pedestals* are recommended. Keyed fire blocks 17 x 11 x 15 x 18 in. are pref. to brick for *arch construction*. The life of the cooling cone is materially increased by air cooling or water jacketing the upper part.

Rotary kiln. *Pulverized coal* is preferable to producer gas. The *diam. of the stone* should be smaller than 2.5 in. and larger than 0.25 in. *Dust* should be eliminated by washing or screening. The waste heat in the gases leaving the kiln is large and should be recovered with *waste heat boilers* if the power can be used. A kiln burning 4 tons of lime per hr. would be good for 180 h. p. A *rotary cooler* through which the air for combustion passes is recommended. Sil-o-cel blocks should be used between the brick lining and the steel shell of the rotary kiln to reduce heat losses. *Chem. control* of the waste gases and *pyrometers* installed in the wall of the kiln are recommended. ED.

79. Theory of iron Portland cement. F. SORCEL. *Rev. Mat. Constr. Trav. Pub.*, **136**, 3 (1921).—Iron Portland cement is a ground mixture, composed of 70% clinkers, made by burning slag and lime stone together, and of 30% granular basic slag. Passow has found that the strength of the cement depends greatly upon whether the base slag is in a vitrified or devitrified state. Some base slags, shown by microscopic examination to be devitrified, gave poor cements. The same base slags were then fused and supercooled by being poured into cold water. This treatment gave clear vitrified products. The resistances to compression and tension were greatly increased by using these vitrified products for cements. LOUIS NAVIAS

80. "Mazout" (burning oil) as fuel for lime-kilns. A. STOLL. *Rev. Mat. Const. Trav. Pub.*, **142**, 129–130 (1921).—"Mazout," the liquid residue from the distillation of benzine and kerosene from petroleum can be used for firing vertical lime-kilns. Six burners situated in the mouth of the kiln are used. Sketches of kiln and burner given. LOUIS NAVIAS

81. The use of fused cement in reinforced concrete structures. L. MALPHETTES. *Rev. Mat. Constr. Trav. Pub.*, **141**, 105–106 (1921).—M. criticizes Magny's comparison of cost figuring of reinforced concrete structures

made (1) with fused cement and (2) with Portland cement. For Portland cement, Magny uses the official specifications for a compression strength of 28% of that obtained after 90 days setting for a 1 : 3 mortar, namely, about 35 kgs. per sq. cm. For the fused cement, Magny allows a compression resistance of 150 kgs. per sq. cm. which is about 35% of the resistance measured by him. M. suggests that two similar structures be built, using Portland cement in one and fused cement in the other. By testing them similarly, the proper coefficients may be determined for use in calculating their comparative costs. LOUIS NAVIAS

82. Concrete-cement brick. M. BOUSQUET. *Rev. Mat. Constr. Trav. Pub.*, **140**, 92–95 (1921).—Brick is made of a mixture of cement and sand. Photographs and descriptions of presses and concrete mixers are given. LOUIS NAVIAS

83. Progress in cement making. L. MALPHETTES. *Rev. Mat. Constr. Trav. Pub.*, **140**, 81–84 (1921).—Three new types of cement have lately appeared. (1) Fused cement—bauxite and lime are intimately mixed and then fused. (2) Hydraulic lime is converted to clinkers by heating in a rotary kiln. The mass is quickly cooled, and then ground. (3) Schist cements—coal-mine schists, having roughly the composition, fixed C and volatile matter 40%, SiO_2 36%, Al_2O_3 15%, Fe_2O_3 9% have been mixed with lime and burned, yielding a good cement. 100 kgs. schist and 240 kgs. lime yield 200 kgs. cement. The 40 kgs. of fixed C and volatile matter yielded by the schist is the only fuel used in the kiln. Le Chatelier's formula for the formation of $SiO_2.3CaO$ in artificial cements does not hold for fused cement. Bied states that the latter contains $SiO_2.2CaO$ and $Al_2O_3.CaO$. Neither the theories nor the proper conditions for reaction for any of the above cements have been worked out. M. puts forward these examples to show the need of an industrial cement research laboratory in France. LOUIS NAVIAS

84. Economic quarry exploitation. D. S. *Rev. Mat. Constr. Trav. Pub.*, **138**, 49–53 (1921).—Plans and description of a plant for using quarry waste. LOUIS NAVIAS

85. Modern plaster plant. M. J. DUCHEZ. *Rev. Mat. Constr. Trav. Pub.*, **138**, 54–56; **139**, 76–78 (1921).—Description, photographs of machinery and plans of an automatic plant. LOUIS NAVIAS

86. The sudden disintegration of clinkers on cooling in the air. J. DAUTREBANDE. *Rev. Mat. Constr. Trav. Pub.*, **138**, 46–48; **139**, 72–73 (1921).—Clinkers directly from the kiln have been found to disintegrate either (*a*) partially or (*b*) totally. This will occur when the proportions of the ingredients are not balanced so as to give the proper ratios for the $SiO_2.3CaO$ compound necessary for a good cement. $SiO_2.2CaO_2$ is not desirable in a cement for it has no bonding properties. In partial disintegration (*a*) the ratio may be upset by the introduction of SiO_2 from the fuel, if it has a high ash content (50% of which may be SiO_2) and from a furnace brick lining that has been under fired. Poor heat distribution and under firing will produce $SiO_2.2CaO$ and free lime, the temp. not being high enough to produce $SiO_2.3CaO$. When

the whole mass falls to dust (*b*) the cause may be due to under or over burning; in the latter case the $SiO_2.3CaO$ is changed to $SiO_2.2CaO$. Lack of sufficient Fe_2O_3 will cause disintegration for Fe_2O_3 helps in the formation of the SiO_2.-$3CaO$. Either (*a*) or (*b*) makes a poor cement. If, however, they are plunged into cold water, the clinkers remain intact, and when ground, give fairly stable cements. D. states that this shows that $SiO_2.2CaO$ exists in two allotropic forms. LOUIS NAVIAS

87. Wetting of coal for continuous lime kilns. LE GEUN. *Rev. Mat. Constr. Trav. Pub.*, **136**, 1–2; **137**, 21–23 (1921).—Water vapor is used in the burning of lime and cement, as a means of combustion, and as an accelerator in the reaction $CaCO_3 = CaO + CO_2$. Water is found in the fuel, and in the lime stone as adsorbed moisture and as water of constitution. As these quantities are not sufficient, the deficit is made up by introducing into the kiln wet powdered fuel. Part of this water passes through the kiln undecomposed, heating up the colder mass on condensation, or abstracting heat on vaporization. The heated fixed carbon of the coal combines with the remaining water vapor, $C + H_2O = CO + H_2$, forming water gas, which burns. If too much water is introduced there will be a great absorption of heat due to the vaporizing of the water, and as a result the kiln will cool, and the product will be only partly decomposed. *Limestone loses its CO_2 faster and at a lower temp. in a current of water vapor, than in a current of dry air.* The following equation may be used to determine the quantity of water to be added to the fuel to take care of all reactions for the best results.

$$A = 1.5\,C - h - \frac{100}{d}\,(10H - B)$$

Where A = litres of water added to wet 100 kgs. of fuel. C = % of fixed carbon in fuel, h = % of water in fuel, d = no. of kgs. of fuel used for 1000 kgs. of crude limestone. H = % of water adsorbed and combined in the limestone. B = coefficient which takes into account the variations of CO_2 found in the limestone. Experimentally B has been found to be 50 for fat limestones (containing 0–4% clay), 30 for hydraulic limestones (containing 10–12% clay) and 10 for natural limestone cements (containing 20–22% clay). As raw clay contains water of constitution, less water B has to be added if the % of clay in the limestone is higher. 12 gms. of C theoretically combine with 18 gms. of H_2O, so the ration of 1 : 1.5 is indicated in the formula. Example: A coal contains 72% fixed carbon and 3% moisture, so $C = 72$, $h = 3$. 133 kgs. of coal are needed for 1000 kgs. of crude limestone, hence $d = 133$. The limestone averages 10.5% adsorbed moisture and 1.5% water of constitution, so $H = 12$. $B = 30$. $A = (1.5 \times 72) - 3 - \frac{100}{133}(10 \times 12) - 30 = 37.5$ litres. LOUIS NAVIAS

88. A new artificial cement plant. L. MALPHETTES. *Rev. Mat. Constr. Trav. Pub.*, **138**, 41–43; **139**, 66–71 (1921).—A general description, plan, and some photographs of the plant of the "Societe des chaux et ciments du Languedoc" at Ranteil, France, producing 20,000 tons annually.
LOUIS NAVIAS

89. Urgent request for a cement laboratory. J. BIED. *Rev. Mat. Constr. Trav. Pub.*, **138**, 43–45; **139**, 61–63 (1921).—A plea to the cement manufacturers (of France) to form a joint laboratory where research work may be systematically carried out. The present ignorance of the properties of the silicates and aluminates of calcium and of the mechanism of the many reactions occurring in the preparations and setting of cements, is emphasized.
LOUIS NAVIAS

90. Cement tile. M. CHARPENTIER. *Rev. Mat. Constr. Trav. Pub.*, **139**, 63–66; **140**, 87–89 (1921).—Composition: Artificial cement 22.3–24.2%, washed sand (3 mm. screened) 67.1 to 69.7%, color oxides 0.5%, water 7.5–8.2%. Such tile have fair resistance to compression, are interchangeable, impermeable to water, non-porous, withstand freezing and rapid heat treatments, hold color, mixed with the body or as a glaze well, and look like terra cotta, in place of which they may be used. LOUIS NAVIAS

PATENTS

91. Process for controlling the setting of cement products. CHARLES L. NORTON. U. S. 1,379,204, May 24, 1921. The method of producing a flat relatively thin stone-like body of hydraulic cement of uniform exterior appearance and water absorbtive capacity which comprises confining the same during the setting operation between two opposite restraining surfaces and maintaining an atmosphere of approximately 90 per cent humidity about the edges thereof. (*C. A.*)

92. Keene's cement. W. HOSKINS. U. S. 1,370,968, Mar. 8. Keene's cement stock is produced by passing finely subdivided gypsum continuously to neutralize all acidity. (*C. A.*)

93. Cements. H. D. BAYLOR. Brit. 155,431, Nov. 8. 1919. Cement is rendered slow-setting, plastic, and waterproof by adding CaO and sufficient water to hydrate. (*C. A.*)

94. Quickly solidifying cement. R. OGAWA. Japan 36,334, May 7, 1920. Clay, containing above 60% SiO_2, above 20% Al_2O_3 and below 10% Fe_2O_3 is mixed with lime in the ratio $CaO/(SiO_2 + Al_2O_3 + Fe_2O_3) = 2$ and the mixt. is burned at 1500–1550° to a clinker, and then mixed with 4% mixt. of natural gypsum and plaster of Paris in the ratio 3 : 1, crushed and sieved. The product solidifies completely within 3 hrs. (*C. A.*)

95. Magnesia cement. M. ÔURA. Japan 35,971, March 12, 1920. The cement is prepd. by mixing together (1) and (2). (1) Mixt. of 60 parts MgO and 10 parts of fibrous substance of vegetable or animal origin, *e. g.*, chaff or powdered cork. (2) Ten parts of soln. of powdered *Hydsome rivieri* and *Gloiopeltis furcata* are mixed with 15 parts asbestos or kieselguhr, dried and powdered and mixed with the proper pigment and 5 parts of burnt alum. (*C. A.*)

96. Artificial stone. R. SHINYA. Japan 36,376, May 13, 1920. The stone is prepd. by thoroughly mixing 1.8 1. magnesite, 1.08 1. ZnO and 0.72 1. glass powder with 1.44 1. $MgCl_2$ soln. (30° Bé). (*C. A.*)

BOOK

97. Riepert: Zement-Kalender 1921. Charlottenburg: Zementverlag. 382 pp. M10.50. For review see *Tonind.-Ztg.* **45,** 104 (1921). (*C. A.*)

ACTIVITIES OF THE SOCIETY

Amendment to Rules

September 23. The following amendment to rules was carried, 115 votes being cast: 106 affirmative, and 9 negative.

In Article II, MEMBERSHIP, section (1) was amended to include the words, "Industrial Association Members." Section (8) was amended to include the words, "Industrial Association Members." A new paragraph was inserted: "Industrial Association Members must be organized groups of manufacturers, who being interested in the advancement of ceramic arts and sciences shall make, for this purpose, such financial contributions as are prescribed in Article III."

In Article III, DUES, a new paragraph reads: "Industrial Association Members shall pay such annual dues in monthly installments or single payment, as shall be agreed upon by the Association and the Board of Trustees, but such dues shall not be less than $480.00 annually."

New Members received during September

Associate Resident

Bales, Cecil E., Louisville Fire Brick Works, Highland Park, Ky.

Burt, N. P., Great Western Stove Co., Leavenworth, Kansas.

Doane, G. Earl, Poplar Bluff, Mo., Doane Consulting Service.

Jackson, Wynne L., 111 S. Kilpatrick Ave., Chicago, Ill., Metallurgist and Chemist, Wolff Mfg. Co.

Montgomery, R. A., Springfield Paving Brick Co., Springfield, Ill.

Quay, Paul Q., 15620 Euclid Ave., East Cleveland, Ohio, Cleveland Metal Products Co.

Rennieburgh, Cedric L., 625 W. Main St., Zanesville, Ohio, American Encaustic Tiling Co.

Rushmore, Murray, 120 West 8th St., Plainfield, N. J.

Stamm, Charles L., 212 W. 2nd St., Mt.Vernon, N. Y., Ward Leonard Electric Co.

Wright, M. H., Tennessee Enamel Mfg. Co., Park Ave. & Railroad, West Nashville, Tenn.

Associate Foreign

Kanashima, Shigeta, Tokio Technical College, Asakusa, Tokio, Japan.

Maruyama, Junkichi, 7 Icchome, Gojotori, Chikko, Osaka, Japan, Kagoshima Electric Railway Co.

Corporation

The Strong Manufacturing Company, Sebring, Ohio.

NECROLOGY

Chester L. Sharp, president of the Sharp-Schurtz Co., died Thursday, August 25th, 1921, from an attack of pleural-pneumonia contracted while attending the meeting of the Merchant's and Manufacturer's Exposition at Lancaster, Pa. Mr. Sharp started work in the glass industry as mechanical engineer for the Columbus Glass Company at Lancaster and later became designing and construction engineer for Ball Brothers Company of Muncie, Indiana. Returning to Lancaster as secretary of the Frink Laboratories and the Frink Pyrometer Company, he, in partnership with P. P. Schurtz, purchased the Frink laboratories when Mr. Frink departed for Europe. Mr. Sharp's sudden death will be felt as a severe loss in the glass industry.

AMERICAN CERAMIC SOCIETY

CORPORATION MEMBERS, 1920-1921

Abrasive Company
Acme Brick Company
Alexander Hamilton Institute
American Dressler Tunnel Kilns, Inc.
American Emery Wheel Works
American Encaustic Tiling Company
American Rolling Mill Company
American Terra Cotta & Ceramic Co.

Bausch & Lomb Optical Company
Beaver Falls Art Tile Company
Benjamin Electric Mfg. Company
Bird & Company
Brick and Clay Record
Buckeye Clay Pot Company
W. G. Bush & Company

Canton Stamping & Enameling Company
Carborundum Company
Champion Ignition Company
Champion Porcelain Company
Chicago Crucible Company
Colonial Company
Coonley Mfg. Company
Cortland Grinding Wheel Company
Crescent Refractories Company

Dings Magnetic Separator Company
H. L. Dixon Company
B. F. Drakenfeld & Company, Inc.
Dunn Wire Cut Lug Brick Company

East Liverpool Potteries Company
Edgar Plastic Kaolin Company
Elyria Enameled Products Company
Charles Engelhard, Inc.

Findlay Clay Pot Company
Edward Ford Plate Glass Company
French China Company
Frink Pyrometer Company

General Ceramics Company
W. S. George Pottery Company
Gillinder Brothers
Gleason-Tiebout Glass Company
Golding Sons Company

Hall China Company
Hanovia Chemical & Mfg. Company
Harbison Walker Refractories Company
Harker Pottery Company
Harshaw, Fuller & Goodwin Company
Homer-Laughlin China Company
L. J. Houze Convex Glass Company

Illinois Glass Company

Jefferson Glass Company
Johnson Porter Clay Company
Johnston Brokerage Company
Jones Hollow Ware Company

Kier Fire Brick Company
Edwin M. Knowles China Company
Knowles, Taylor and Knowles Company

Laclede-Christy Clay Products Company
Limoges China Company
A. J. Lindemann & Hoverson Company
Lindsay Light Company
Los Angeles Pressed Brick Company
Louthan Manufacturing Company

McLain Fire Brick Company
D. E. McNicol Pottery Company
Macbeth-Evans Glass Company
Maine Feldspar Company
Massillon Stone and Fire Brick Company
Matawan Tile Company
Maxf Grinding Wheel Corporation
Midland Terra Cotta Company
Mississippi Glass Company
Mitchell Clay Mfg. Company
Monongah Glass Company
Moore & Munger
Mosaic Tile Company

National Fireproofing Company
Niles Fire Brick Company
Norton Company

Ohio Pottery Company
Old Bridge Enameled Brick & Tile Co.
Onondaga Pottery Company
Owen China Company

Parker Russell Mining & Mfg. Company
Pennsylvania Pulverizing Company
Pennsylvania Salt Mfg. Company
Perth Amboy Tile Company
Pfaudler Company
Philadelphia Drying Machinery Company
Phoenix Glass Company
Pittsburgh High Voltage Insulator Co.
Pittsburgh Plate Glass Company
Portland Stove Works
Potters Supply Company
Product Sales Company

Reading Fire Brick Works
Reliance Firebrick & Pottery Co., Ltd.
Roessler & Hasslacher Chemical Company
Russell Engineering Company

Salem China Company
John H. Sant & Sons Company
Saxon China Company
Sebring Pottery Company
Smith-Phillips China Company
Square D Company
Standard Pottery Company
Standard Sanitary Mfg. Company
Star Porcelain Company
Stark Rolling Mill Company
Steubenville Pottery Company
Stockton Fire Brick Company
Streator Clay Mfg. Company
Strong Mfg. Company

Taylor, Smith & Taylor Company
R. Thomas & Sons Company
Trenton Flint & Spar Company

United States Glass Company
U. S. Smelting Furnace Company
Universal Clay Products Company

Veritas Firing System
Vitro Manufacturing Company
Vodrey Pottery Company

Wahl Company
Warwick China Company
Washington Brick, Lime & Sewer Pipe Co.
West End Pottery Company
Western Stoneware Company
Whitall-Tatum Company

JOURNAL

OF THE

AMERICAN CERAMIC SOCIETY

A monthly Journal devoted to the arts and sciences related to the silicate industries.

Vol. 4 **November, 1921** **No. 11**

EDITORIAL

THE EXECUTIVE CONFERENCE

The Executive Conference held at the Hotel Commodore, New York City, Sept. 15th and 17th, was attended by approximately fifty past or present officers, members of committees, etc.

The discussion covered an outline of topics that was prepared by the Organizing Secretary, Mr. Purdy, constituting a survey of the problems pertaining to the Society as a whole, and more particularly those pertaining to the efficient functioning of the Sections and Divisions.

As a result of the discussions, certain changes in the constitution and in the by-laws were proposed, which were read at the regular meeting of the Society, held on Sept. 16th, Ceramic Day, at the Chemical Exposition. These will be submitted to the membership for vote.

Further, a number of recommendations were made to the board of trustees for their consideration and action. The results of the final action on the various proposals and recommendations will be published as soon as the vote has been completed, which should be at an early date.

It is beyond question that the Society is on the threshold of a greatly extended program in accordance with its original and reaffirmed purpose, *viz.*, "To advance the ceramic arts and

sciences." In the interpretation of this purpose a closer contact with the ceramic manufacturer is being developed. In its finality, the activities of the Society redound to the economic benefit of the manufacturer in particular and to the economic and aesthetic benefit of humanity in general.

This program of larger service will naturally require more money. The board of trustees has inaugurated the agencies of this service with the conviction that all ceramic entities, industrial associations, corporations, and individuals, will be pleased to contribute proportionately to the financing of the project and will be assured that every dollar so invested has been most advantageously placed.

It is the duty and personal privilege of each member of the Society to give his quota of the larger service and to help solicit the needed financial support.

F. K. PENCE.

TO AUTHORS OF PAPERS

Authors' manuscripts and original drawings are preserved in this office for twelve months following date of publication, after which they are destroyed. Authors desiring any of this material returned to them should notify the Editor's office within the twelve month period.

ORIGINAL PAPERS AND DISCUSSIONS

POSSIBILITIES OF TERRA COTTA CASTING

By R. F. Geller[1]

ABSTRACT

Experimental method.—The casting properties, viscosity, specific gravity and drying behavior of three kaolins, two ball clays, one fire-clay and four representative commercial bodies, together with terra cotta clays, were studied. The clays and bodies were treated with varying amounts of salts and cast in the form of small ashlars.

Conclusions.—Kaolins have an open structure but do not develop strength on drying. Bonding properties are furnished by ball clays which, however, tend to seal against the mold. Commercial terra cotta bodies tested do not possess good casting properties but can be modified through a study of the component clays. Mechanical difficulties attending the casting of terra cotta render the feasibility of the process doubtful at the present time.

Introduction

A general tendency toward improvement of terra cotta and its method of manufacture has made it desirable to study the possibilities of the casting process for the formation of clay ware as applied to this important industry. The present work consists of a preliminary study of the casting behavior of three kaolins, two ball clays and one fire-clay. This is followed by a number of laboratory tests in which representative commercial terra cotta bodies were treated with different and varying amounts of salts and the effect on their casting properties, viscosity, "specific gravity" and drying behavior noted.

The following commercial bodies and clays were tested: Two New Jersey bodies, as well as the clays used in their manufacture; one Indiana body; and one body used in California. In

[1] Received July 18, 1921. Published by permission of the Director, Bureau of Standards.

the preliminary work, washed North Carolina, Georgia and Florida kaolins, Tennessee and Kentucky ball clays and an Arkansas fire-clay were used. Whenever necessary, the clays were dried and crushed to pass a twenty mesh sieve before placing in the blunger where the body was thoroughly mixed to a stiff mud consistency. When barium carbonate was used to react with sulfate present as an impurity in the clay, it was added as a powder during this stage. Mixing was then continued for an hour before addition of the deflocculating agent. After the reaction with the salts and required additions of water had brought the mixture to the proper consistency it was poured into plaster molds to cast. The slip was considered right for casting when it would just flow from a container. "Specific gravity" determinations were made by simply obtaining the weight of 100 cc. of the slip, and comparing it with the weight of 100 cc. of water and the viscosity was measured by means of a viscosimeter similar to the one used by Bleininger.[1] Linear drying shrinkage was obtained on the cast piece itself, and small samples poured in a plaster mold were used for the water-of-plasticity determinations. The grog used in the testing of the kaolins, ball clays and fire-clay consisted of ground white ware bisque. Fifty per cent of this grog passed the 15 mesh sieve and was retained on the 40 mesh and the balance passed through the 40 mesh. The commercial clays were mixed in equal proportions with grog furnished by the manufacturer. All the casting tabulated in table No. 1 was done in plaster molds designed to form an ashlar $6 \times 6 \times 4$ inches, and, in order to obtain comparative results, an equal time was allowed before removing specimens from the mold. In certain cases where it was obvious that the piece would not bear removing the time was lengthened as noted.

Considering the first ten experiments in the table, we see that the kaolins in no case produce a good wall, although the specific gravity of the slip and the thickness of the cast wall are satisfactory. The kaolins as a class produce a slip which is heavy, will not flow in the viscosimeter and yet is short. It has none of that stickiness which so characterizes a glass pot casting slip

[1] Bleininger, A. V., "Notes on Castings," *Trans. Am. Ceram. Soc.*, **17**, 331 (1915).

and when poured seems to slide over itself rather than string out and flow, as flowing is ordinarily thought of. The walls have no strength and either slump or crack in drying.

With 0.1 per cent salts, the fire-clay produces a slip similar to that of a kaolin in the way it casts, but it also has considerable gumminess. With 0.2 per cent salts the gumminess increases and the specific gravity is raised over eight per cent. The slip now shows a tendency to form a dense wall against the sides of the mold. This wall, which is usually about one-eighth inch thick at the maximum and will form in about ten minutes, seems to act as a seal which retards and even stops further casting through absorption of water by the plaster.

With the ball-clays, which contain large amounts of colloidal matter and are very fine grained, the greatest amount of reaction with salts is obtained. The ball-clay slips are of high specific gravity and extremely sticky. They are quite mobile during, and immediately after, agitation but set quickly to a "soft mud" consistency. The Tennessee ball-clay forms a seal almost immediately after being poured and, although the entire mass becomes thick, the actual cast wall does not exceed one-fourth inch after two hours' time. The Kentucky ball-clay has less tendency to seal but the wall formed is weak.

It would seem from these results that the more open structure of the kaolins is a desirable feature in casting in order that passage ways may be kept open through the wall already cast to facilitate the absorption of further amounts of water by the mold. This is also shown by the casting behavior of the coarser grained Kentucky ball-clay. On the other hand, colloid matter either organic or inorganic is necessary as a bonding element. This colloidal material is carried in super abundance by the ball clays and it would seem logical then to so blend a "fat" clay with one lean in colloids as to procure a body of the desired quality. Since the material most widely used in making terra cotta contains a semi-fire clay, one would expect it to vary from a fine grained and very plastic body to one of coarse grain and little plasticity. It was, therefore, determined to study the clays used in this industry individually in order that, their properties being known, they might be blended to produce a mixture suitable for casting.

Clay No. 1 of body A cast satisfactorily with every combination of salts. This clay is fine grained and exceedingly plastic. When using commercial sodium silicate (water glass) a viscous slip is formed which seals in casting and in every way resembles that of a ball-clay. This clay is interesting because of its wide range of reactions to various combinations of salts. Using barium carbonate and sodium silicate, the slip has a high viscosity. When sodium carbonate replaces the sodium silicate the gumminess is reduced, and this becomes even more noticeable when the barium carbonate treatment is omitted. When the soluble barium chloride was substituted for the carbonate, sodium silicate being used as the deflocculating agent, the slip formed had no strength. Lastly, when the barium chloride and sodium carbonate combination was used, the resultant slip had no resemblance to the first obtained but appeared and cast up like a kaolin.

Clay No. 2 of the same body is a mixture of what appears to be a ball-clay and a coarse grained fire-clay high in ferruginous impurities, together with decayed organic matter. As shown in test No. 19 a good wall is cast on addition of 0.4 per cent of sodium silicate, which, however, causes efflorescence on drying. It may be said that this clay had no tendency to seal but formed a wall of insufficient strength.

Clay No. 3 is a mixture resembling the preceding one but having a comparatively small amount of the fine grained material and considerably more of the coarse grained clay. In contrast to body No. 1 this mixture developed the best qualities without the use of the barium salt, but the walls in no test developed satisfactory strength. On standing this slip becomes thinner instead of setting to the "gel" state, as was found to be the case with every other clay tested. The reason for this phenomenon is not evident from the data at hand.

Body No. 4, a mixture of what resembles an impure and a comparatively pure fire-clay, has considerable plasticity and a coarse grained structure. With 0.2 per cent of sodium silicate, the slip is "short" similar to a kaolin and when the salts are increased to 0.3 per cent a slip is formed which sets quickly when agitation ceases but does not form a seal in the mold. The wall,

TABLE I

Test No.	Materials used	0.1% $BaCO_3$	Salts used in per cent of dry body*[2]	Max. wall cast in inches	Time required to set, in hrs.	Time required to remove from mold, in hrs.	Quality of wall	"Specific gravity"	Viscosity*[1]	Water of plasticity %	Dry shrinkage: dried at 110°C; per cent of wet length	Remarks
1	N. C. kaolin 50% grog	no	01. M	1	1½	3	poor	1.85	—	——	4.0	Slip would not run. Not gummy. Efflorescent, cracked in drying.
2	Ga. kaolin	no	0.1 M	¾	2	3	poor	1.80	M	——	5.0	Slip would not run. Not gummy.
3	Fla. kaolin 50% grog	no	0.1 M	1	2½	3½	poor	1.54	L	43.7	7.5	Slip would not run. Not gummy.
4	Tenn. ball 50% grog	no	0.1 M	½	2	3	medium	1.82	H	26.8	5.5	
5	Discarded											
6	Ky. ball 50% grog	no	0.1 M	⅞	2	3½	poor	1.70	M	32.5	6.0	
7	Ark. F. C. 50% grog	no	0.1 M	¾	1⅓	3½	poor	1.70	—	32.0	4.2	Sets up like a kaolin. Walls cracked in drying.
8	Ark. F. C. 50% grog	no	0.2 M	¾	1¾	3	medium	1.85	M	23.9	6.5	Entire mass sets. Walls soft but did not slump.
9	Ky. ball	no	0.2 M	⅝	1¾	3	poor	1.80	M	26.0	4.5	
10	Fla. kaolin	no	0.2 M	¾	2	3	poor	1.64	—	35.8	6.5	Slip thin but not viscous. Efflorescent and cracked in drying.

*[1] H: high viscosity; M: medium; L: low.

*[2] Salts used—M: mixed salts—4 parts Na_2SiO_3 to 3 parts Na_2CO_3; CO_3: Na_2CO_3; SiO_3: Na_2SiO_3.

TABLE 1 (*continued*)

Test No.	Materials used	0.1% $BaCO_3$	Salts used in per cent of dry body*[2]	Max. wall cast in inches	Time required to set, in hrs	Time required to remove from mold, in hrs.	Quality of wall	"Specific gravity"	Viscosity*[1]	Water of plasticity %	Dry shrinkage: dried at 110°C; per cent of wet length	Remarks
11	Body A[1] Clay No. 1 and grog	no	M	5/8	2	2½	poor	1.74	M	29.2	4.0	Efflorescence. Cracked in drying. Left in mold over night.
12	do.	no	0.2 CO_3	11/16	2	—	poor	1.80	M	28.4	4.5	
13	do.	0.1 $BaCl_2$	0.2CO_3	¾	3	—	poor	1.70	—	33.8	4.5	Slip more like a kaolin. No gumminess.
14	Discarded											
15	Clay No. 1 and grog	yes	0.2 SiO_3	5/16	1½	—	medium	1.87	H	23.6	4.0	Left in mold over night. Very viscous.
16	do.	yes	0.2 CO_3	½	2	—	poor	1.81	H	28.7	7.5	do.
17	do.	0.1 $BaCl_2$	0.1 SiO_3	⅞	3	4	medium	1.64	L	38.5	6.5	Walls appeared fairly strong but broke in removing. Mass in center remained thin.
18	Clay No. 2 and grog	yes	0.2 SiO_3	¾	3	3½	poor	1.64	L	38.7	5.0	Sandy clay. Acts like a kaolin.
19	do.	yes	0.4 SiO_3	1	2	5	good	1.80	H	28.8	4.0	Good wall but efflorescent in drying.
20	do.	yes	0.4 M	11/16	2	3	poor	1.76	M	30.3	—	
21	do.	yes	0.4 M	1	5	6	poor	1.61	M	37.8	5.0	Walls did not break but slumped.
22	Clay No. 3 and grog	yes	0.2 SiO_3	½	2	3	medium	1.92	H	20.6	3.0	½" set up but 1" could be left.
23	do.	yes	0.2 CO_3	9/16	2	3½	poor	1.82	L	30.3	4.0	Wall had actually set up 9/16" in 1 hr. Slip in center more watery after standing.
24	do.	no	0.2 M	1	2	3½	medium	1.86	M	27.7	5.0	Slight efflorescence.

[1] Clays No. 1, 2, 3 and 4 are those composing Body A

TABLE I (continued)

Test No.	Materials used	0.1% $BaCO_3$	Salts used in percent of dry body*2	Max. wall cast in inches	Time required to set, in hrs.	Time required to remove from mold, in hrs.	Quality of wall	"Specific gravity"	Viscosity*1	Water of plasticity %	Dry shrinkage: dried at 110°C; per cent of wet length	Remarks
25	Body A Clay No. 3 and grog	yes	0.2 M	¾	2	3	poor	1.88	M	23.5	4.0	Center more water after standing.
26	Clay No. 4 and grog	yes	0.2 SiO_3	⅞	2½	—	poor	1.74	—	31.0	5 0	Slip like kaolin mix. Left in mold over night.
27	do.	yes	0.3 SiO_3	1¼	3	4	good	1.87	H	25.4	6.0	Sets up well but cracked in drying.
28	do.	yes	0.3 M	1	3	6	medium	1.84	—	26.9	4.5	
29	12½% Clay No. 1, 37½% Clay No. 4 and 50% grog	yes	0.25 SiO_2	1¼	2	4	good	1.86	H	25.8	5.5	Wall good. Slip set quickly.
30	50% Clay No. 4 and grog, 50% Body D	yes	0.25 SiO_2	1	2	3¼	medium	1.86	H	25.9	4.5	Cracked in drying.
31	25% Body B, 75% Clay No. 4 and grog	yes	0.25 SiO_2	1	3	3½	medium	1.91	M	23.2	5.0	Only ½" actually cast. Walls did not slump.
32	50% Body D, 50% Clay No. 4 and grog	yes	0.2 M	11/16	2	3	poor	1.75	—	33.8	5.5	Acts like kaolin mix. Slip not viscous, acts like kaolin.

TABLE 1 (*continued*)

Test No.	Materials used	0.1% $BaCO_3$	Salts used in per cent of dry body*2	Max. wall cast in inches	Time required to set, in hrs.	Time required to remove from mold, in hrs.	Quality of wall	"Specific gravity"	Viscosity*1	Water of plasticity %	Dry shrinkage: dried at 110°C; per cent of wet length	Remarks
33	25% Body D, 75% Clay No. 4 and grog	yes	0.2 M	1	3	3	poor	1.80	L	30.4	—	Slip runs easily, does not string.
34	25% Body D, 75% Clay No. 4 and grog	yes	0.2 M	1	2	3	medium	1.83	L	27.3	5.0	Slip apparently had a good casting consistency.
35	Body B	yes	M	3/4	2	3	poor	1.85	H	26.1	5.5	Tends to seal.
36	do.	yes	CO_3	5/8	2	—	poor	1.67	L	37.4	6.5	Set in mold over night. Slip not gummy.
37	do.	yes	0.3%	7/16	1	—		1.73	M	33.3	—	Tends to seal.
38	Body C	yes	M	3/8	2		poor	1.90	H	22.1	7.5	Tends to seal. Left in mold over night. Entire mass thick gum.
39	Body D	yes	M	7/16	2	4	medium	1.76	M	30.3	7.0	Tends to seal. Walls fairly strong considering thickness.
40	Body B, 25% Clay 1, 25% Clay 2, 50% grog A	yes	0.25% M	5/8	2	—	poor	1.91	M	24.2	4.5	Tends to seal. Left in mold over night. Sets quickly.
41	Body B, 25% Clay 3, 25% Clay 4, 50% grog A	yes	0.25% M	1/2	2			1.92	M	21.6		Slip does not set up.
42	Body C	yes	CO_3	1/2	1½	—	poor	1.81	—	29.6	5.5	Left in mold over night. One in. wall left but only ½" firm. Does not seem to set up.

to all appearances strong, sets up in three hours to the required thickness. The shrinkage, six per cent, is comparatively large, however, and the piece cracks in drying. Since the clay is satisfactory in every way but the drying behavior, it was decided to add some of the clay No. 1 in order to obtain the necessary bond. As shown in test 29, a body was prepared containing 12½ per cent clay No. 1, 37½ per cent clay No. 4 and 50 per cent grog. With 0.25 per cent of sodium silicate, the resultant slip formed a wall $1^1/_4$ inches thick and very strong, in two hours' time. The piece removed easily from the mold and did not fail in drying.

Body B, as the results of test 35, 36, and 37 show, was not adapted to casting without modification. The mixture, which apparently had a high bond clay content and a low percentage of grog, was very plastic and would seal in the mold. The individual clays of this body were obtained, but not in sufficient quantity to make the desired number of tests. Clay No. 1 was to all appearances a ball-clay, clay No. 2 a fine grained plastic clay almost white in color, and clays No. 3 and No. 4 had the properties of semi-fire clays. From the two preliminary tests which it was possible to make with the small samples furnished, shown in tests 40 and 41, it would seem that a small proportion of clay No. 1 blended with either or both of the fire clays would produce a slip favorable for casting.

Body C, representing the mid-western states, formed a slip too high in viscosity for casting. It was mixed with a lean clay, (see test No. 31) in the ratio of one to three but even then the tendency to seal was too great and only one-half inch of wall was formed after a reasonable length of time. The strength, however, was very good and a study of the individual clays would no doubt result in the making of a desirable body.

Body D, from California, was of a buff color and contained a large amount of comparatively coarse inert material. The casting test of this body was not promising. There was a tendency to seal without the mass setting-up to any stiffness. When blended in equal parts with a lean clay (see test 30) the casting proceeded normally but the structure formed was not sufficiently strong to withstand drying strains. It would seem that a coarse grained plastic clay, such as a fire-clay, would help the general

qualities of this body for casting. Several tests which have been suggested were not carried out in this work because of lack of materials and time, but sufficient data are here shown to indicate that, based on a study of the several clays, other combinations suitable for casting besides that of test 29, can be developed.

The main difficulty encountered in this work lies in the handling of the slip. In the making of glass pots a large amount of slip is concentrated in the making of one piece, and the points where casting is done are proportionately fewer and nearer to the mixer than in the case of a plant for the manufacture of terra cotta. There the pieces are small and numerous and consequently would be scattered over considerable area. To carry the slip to the molds in large containers would necessitate an elaborate system of over-head cranes and to carry the molds to the mixer would mean a carrier system no less expensive. The most convenient system would, of course, be to pump the material. When one considers, however, the viscosity of the mass to be handled as well as the fact that it tends to set, after the nature of colloids, as soon as movement due to externally applied pressure is stopped, it immediately becomes evident that the size of piping and pumping force required would make the cost of the equipment practically prohibitive.

Now, presupposing that the above difficulties have been overcome and that the slip is in the mold, we have the following conditions to be met. Since no cores are used, that portion of the slip in the center of the mold must be removed after the walls have been cast. With the making of pottery this superfluous matter is simply poured out, leaving a uniform shell of material against the mold. In the casting of heavier ware, with a mix containing a large proportion of coarse grog and in which the water content must be kept as low as possible, the slip, originally sluggish, has become "livery" throughout by the time the casting is complete. Consequently the center slip can not be poured out and can be even less readily pumped. Also, there is no sharp demarcation showing the cast portion, so that the bottom and sides of the piece must be worked to the desired uniformity by hand. It is possible of course to obtain a thin

slip and one which will not set to a "livery" mass, but in none of the present tests did such a slip cast a wall of any strength. Having removed the mass from the center of the mold by dipping or some other suitable method, it must be returned to the blunger and agitated until it again becomes uniform and free of lumps. A few trials were made in which this slip was put directly into a second mold, and it was found that the casting properties had been impaired, probably through a setting of part of the colloid. It has been found in the casting of glass pots that it is necessary to treat a slip, which has once set, with a small addition of salts to restore its original ability to cast and this would in all probability hold for the terra cotta slips. This treatment would therefore be necessary in connection with the blunging mentioned above.

The question of webs is also of importance. In casting without a core it would of course be necessary to place these partitions in the piece after removal of the superfluous slip. The webs, in all probability machine-made, would require a very careful control of composition and water content in order to insure shrinkage in drying and burning equal to that of the cast walls. The relative compositions of cast and machine-made bodies could only be determined by individual experimentation.

Casting without a core, the following three conditions have then been found to cause unusual difficulties and expense:

a. The transportation of the slip to the mold.

b. The removal of the superfluous slip from the mold.

c. The treatment of this slip to render it again suitable for casting.

To cast with a core would of course entail an additional cost for material and manufacture but to offset this there are the following savings:

a. Depending on the size of the piece, each mold would require the transportation of 40 to 60 per cent less slip in the first process.

b. There would be no superfluous slip to remove from each mold.

c. There being no waste material, it would not be necessary to transport such material back to the blunger and prepare for recasting.

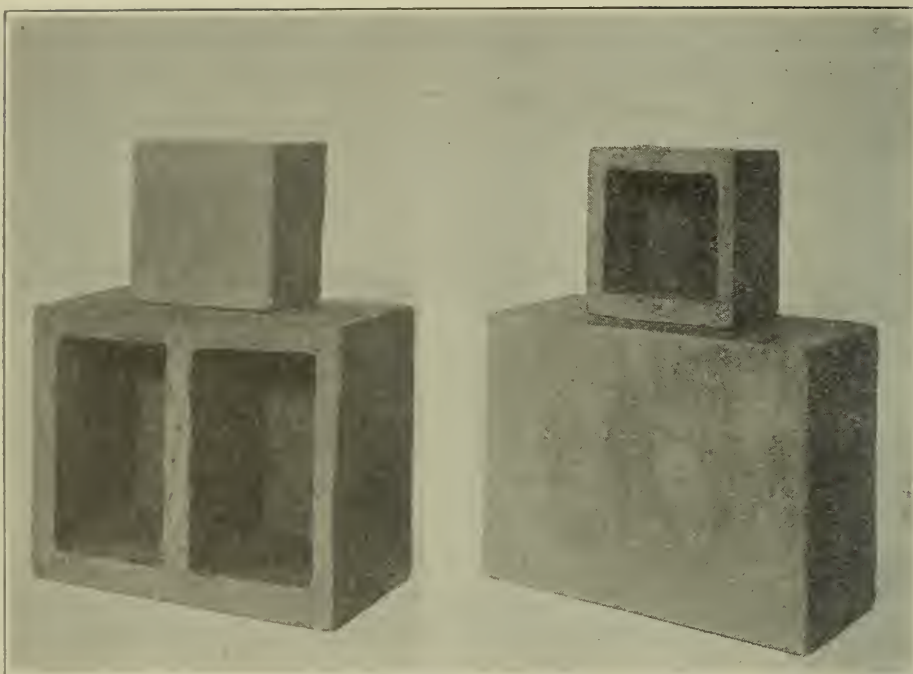


Fig. 1.

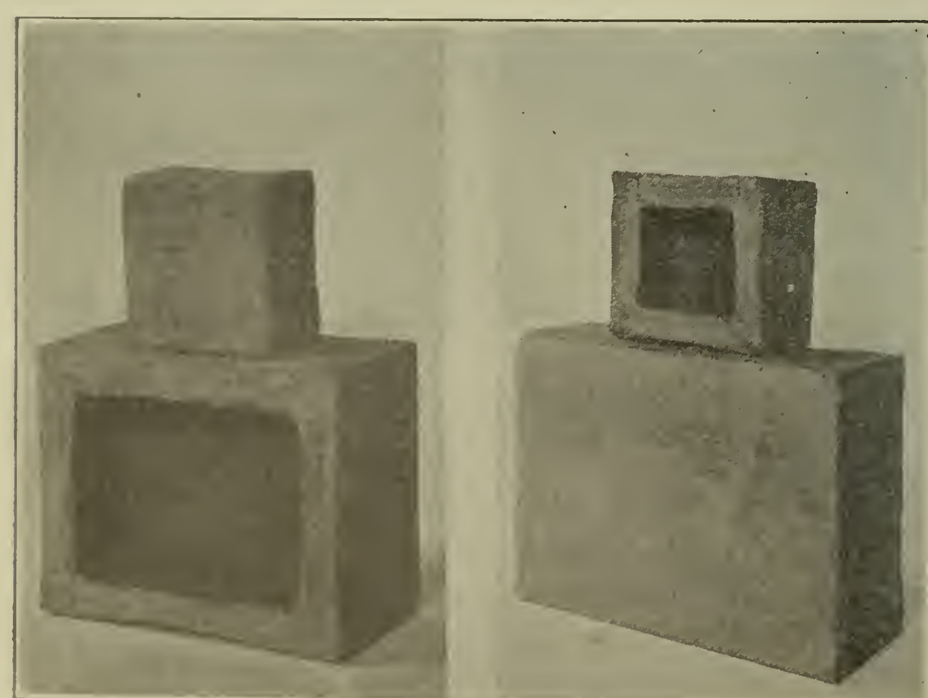


Fig. 2.

d. The same cores could be used for all pieces of approximately the same size and varying only in the different decorative designs.

In order to investigate the feasibility of casting with cores, a few ashlars with approximately one inch thick walls were cast. The specimens were photographed and are shown in figure 1. The test pieces obtained in experiments 19 and 29 are shown in figure 2, together with a larger specimen ($12 \times 9 \times 6$ inches) cast without a core and using the body given in test 29.

From the data as presented in this paper, it would seem that the following conclusions might be drawn concerning the casting properties of kaolins, ball-clays, fire-clays and terra cotta bodies:

a. The open structure of kaolins is a desirable feature in casting but they do not possess sufficient bonding material.

b. The ball clays have sufficient bond, but form a skin against the mold which is too dense to allow the further absorption of water from the slip.

c. Fire clays may have the general casting properties of either a kaolin or the ball clay, depending on their structure and on their potential casting properties due to the salts which they contain as impurities.

d. Commercial terra cotta bodies tested in this work do not possess good casting properties, but may be adapted to this work through a study of their component clays.

e. The mechanical difficulties attending the casting of terra cotta render the feasibility of the process doubtful at the present time.

NOTE ON THE HARDNESS OF GLAZES[1]

By George Blumenthal, Jr.

ABSTRACT

Method of measurement.—The apparatus used (figure 1) consisted of a hardened tungsten-steel point which was allowed to bear on the glaze surface for 3 min. under a pressure of 50 lbs. The hardness was then computed from the dimensions of the resulting indentation. Results were reproducable to about 5 per cent. (See table III.) The presence of ridges and bubbles in the glaze was the principal cause of discordant readings.

Results and conclusions.—The enamels show the lowest and the porcelain glazes the greatest hardness, while the whiteware glazes occupy an intermediate position. The difference in hardness between the enamels and the whiteware glazes is quite marked. There is also a rather well defined difference between the whiteware and the porcelain glazes, but not a sharp separation between the lower and the higher fired porcelain glazes. Enough evidence has been accumulated to show that increased firing of the same glaze will increase the hardness. It appears also that increase in the alumina content brings about greater hardness.

Method

Manufacturers of white ware and table porcelain endeavor to produce as hard a glaze as possible which will resist the mechanical action of cutlery. This requirement may be considered to be a universal one for all types of glazed ware. Unfortunately, however, the determination of hardness is a difficult task and there is no agreement as to the best method of measuring this physical quality. In general, hardness may be defined as the resistance offered by a body to the penetration of a still harder material. Probably the most satisfactory method is that of Brinell, in which the penetration of a sphere into the material to be tested is measured under a standard which causes the penetration. In the present work an attempt has been made to estimate the hardness of several typical

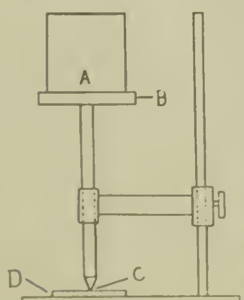


Fig 1

[1] Received July 1, 1921. Published by permission of the Director, Bureau of Standards.

glazes and enamels by means of an adaptation of the Brinell test. The apparatus employed was very simple and is shown in figure 1. It consisted of a hardened tungsten steel point which was caused to penetrate the surface of the glaze under pressure. This procedure of making the test was a very simple one and consisted in placing a 50 pound weight, A, upon the platform B, and allowing it to remain in position for three minutes, after which time it was removed. The pressure upon the steel point was equivalent to several hundred thousand pounds per square inch. The indentation made in the glazed surface was then measured by means of a micrometer microscope, and several diameters of each impression were measured and a number of impressions made on every trial piece. The mean of the several measurements was taken to be the diameter of the impression. One of the difficulties in making this test was the presence of ridges and bubbles in the glaze, which are the principal causes of many discordant readings.

The computation is based on the relation:[1]

$$t = \frac{D}{2} - \sqrt{\frac{D^2}{4} - \frac{d^2}{4}}$$

where t = depth of indentation, D = diameter of the rounded point, d = diameter of indentation, and p = load. The hardness may then be computed from the relation:[1]

$$H = \frac{p}{\pi tD}$$

The hardness of different whiteware and porcelain glazes was determined as well as that of a number of enamels of the type applied on steel. The whiteware and porcelain glazes were applied upon specimens made in the laboratory. In the whiteware glazes of table II, glazes 1, 2, and 3 have the same molecular formula but different percentages of frit were added in each of the three mentioned.

Results

The observations made in connection with tests on a typical whiteware glaze, fired at cone 4, are given in table I. From

[1] Bureau of Standards, *Tech. Paper*, **11**, "Comparison of Five Methods used to Measure Hardness," p. 5.

TABLE I—CHARACTER OF THE INDENTATIONS ON WHITEWARE GLAZES FIRED TO CONE 4

	Diameter of Impression in mm.	Appearance	Impression
1.	0.424	Hardly any bubbles	Sharp
2.	460	Few bubbles	Sharp
3.	.464	Many bubbles	Ragged
4.	.490	Many bubbles and fractured at point of contact	Ragged & chipped
5.	.472	Fractured at point of contact	Ragged & chipped
6.	.478	No bubbles—crazed	Ragged
7.	.412	Few bubbles	Sharp
8.	.404	Few bubbles	Sharp
9.	.488	Bubbly, crazed at point of contact	Ragged & chipped
10.	.466	Few bubbles	Sharp
11.	.432	Few bubbles	Sharp
	Same as above at Cone 6		
1.	.356	Few bubbles	Sharp
2.	——	Immature	Ragged
3.	.366	Slightly pitted	Sharp
4.	.372	No bubbles	do.
5.	.398	Few bubbles	do.
6.	.376	Few bubbles	do.
7.	.346	Few bubbles	do.
8.	.366	Slightly pitted	do.
9.	.372	Few bubbles	do.
10.	.354	Crazed when pressure was exerted	do.
11.	.374	Few bubbles	do.

these results it is apparent that the presence of bubbles in the glaze will lower its hardness decidedly. From the appearance of the indentation it seemed that there was an extremely thin but exceedingly hard layer or film on the surface of the glaze, similar to the enamel on teeth. There was a distinct difference between the surface and the material below it, which showed a crushed appearance. If there were a succession of hard layers the steel point would crush through each, leaving a series of ellipses. This was actually found in the case of the harder glazes, but was absent in those of a softer character.

In order to determine the effect of increased firing on the hardness of the whiteware glazes, the latter were applied to whiteware discs and fired to cone 4—4½ and cone 5½—6. In the cone 4 tests, the hardness fluctuated from 248 to 296, although several specimens were entirely out of this range and were discarded as immature. The hardness of the specimens fired to cone 5½ was from 268 to 298. Another set of whiteware glazes were fired at cones 4 and 6 and the hardness found to vary from 214 to 258 at cone 4, and 261 to 300 at cone 6.

In general, firing to higher temperature, therefore, appears to yield harder glazes. The hardness values for the series of white ware glazes are given in table II. Table III shows the hardness

TABLE II—INCREASE OF HARDNESS WITH INCREASE OF TEMPERATURE

	Whiteware Glazes								Cone 4		Cone 6	
	K_2O	Na_2O	CaO	PbO	ZnO	Al_2O_3	B_2O_3	SiO_2	R	H	R	H
1.	0.173	0.032	0.456	0.217	0.122	0.238	0.271	2.30	0.212	246	0.178	249
2.	.173	.032	.456	.217	.122	.238	.271	2.30	.230	226		
3.	.173	.032	.456	.217	.122	.238	.271	2.30	.232	224	.183	284
4.	.173	.139	.343	.219	.124	.240	.278	2.32	.245	214	.186	280
5.	.177	.243	.233	.222	.125	.243	.279	2.35	.236	220	.199	261
6.	.230	.318		.289	.163	.317	.361	3.06	.239	218	.188	276
7.	.266	.211		.334	.189	.366	.417	3.54	.206	253	.173	300
8.	.317	.059		.399	.225	.437	.497	4.22	.202	258	.183	284
9.	.295	.290		.265	.150	.375	.331	2.79	.244	213	.186	280
10.	.368	.182		.288	.162	.452	.359	3.01	.233	224	.177	296
11.	.478	.045		.305	.172	.570	.380	3.05	.216	240	.182	286

R = Radius of indentation in mm.
H = Hardness of glaze.

TABLE III—ILLUSTRATING THE VARIATION OF THE RESULTS USING A SINGLE GLAZE APPLIED TO 29 DIFFERENT WHITEWARE TEST DISKS.

Composition of glaze suitable: CaO 0.55, K_2O 0.25, PbO 0.20, Al_2O_3 0.27, B_2O_3 0.39, SiO_2 2.96.

	Cone 4		Cone 6	
	R	H	R	H
Mean of 29 tests	0.191	272	0.187	280
Average deviation from the mean a.d.	.0068	10	.004	6
Max. dev. from mean	.019	24	.013	18
Percision Measure $\frac{\text{a.d.}}{\sqrt{29}}$	.0013	2.22	.00088	1.33

R = radiation of indentation.
H = hardness of glaze.

of the same whiteware glaze applied to 29 specimens on discs of the same body composition. The specimens were all prepared at the same time. The table shows the range of values that may be encountered in the same glaze on a number of pieces of ware.

The results obtained on porcelain glazes are compiled in table IV, and those for enamels in table V. It is apparent that a distinct

TABLE IV—HARDNESS OF SOME PORCELAIN GLAZES FIRED AT CONE 16

	CaO	K_2O	Al_2O_3	SiO_2	$Al_2O_3:SiO_2$	R	H	
1.	0.7	0.3	0.30	3.0	1:10	0.146	356	
2.	.7	.3	.375	3.0	1:8	.140	370	
3.	.7	.3	.500	3.0	1:6	.150	346	
4.	.7	.3	.600	3.0	1:5	.156	334	
5.	.7	.3	.750	3.0	1:4	.162	321	
6.	.7	.3	.400	4.0	1:10	.170	306	immature
7.	.7	.3	.500	4.0	1:8	.155	336	
8.	.7	.3	.666	4.0	1:6	.152	342	
9.	.7	.3	.800	4.0	1:5	.147	354	
10.	.7	.3	1.000	4.0	1:4	.149	349	
11.	.7	.3	.500	5.0	1:10	.162	321	
12.	.7	.3	.625	5.0	1:8	.144	361	
13.	.7	.3	.833	5.0	1:6	.142	366	
14.	.7	.3	1.000	5.0	1:5	.151	340	
15.	.7	.3	1.250	5.0	1:4	.153	344	
16.	.7	.3	.700	7.0	1:10	.150	346	
17.	.7	.3	.875	7.0	1:8	.145	362	
18.	.7	.3	1.166	7.0	1:6	.148	350	
19.	.7	.3	1.400	7.0	1:5	.139	372	
20.	.7	.3	1.750	7.0	1:4	.138	374	
21.	.7	.3	.900	9.0	1:10	.155	336	
22.	.7	.3	1.125	9.0	1:8	.160	325	
23.	.7	.3	1.500	9.0	1·6	.158	330	
24.	.7	.3	1.800	9.0	1:5	.148	351	
25.	.7	.3	2.250	9.0	1:4	.147	352	
26.	.7	.3	1.100	11.0	1:10	.144	361	
27.	.7	.3	1.375	11.0	1:8	.143	362	
28.	.7	.3	1.833	11.0	1:6	.151	340	
29.	.7	.3	2.200	11.0	1:5	.138	374	

R = Radius of indentation in mm.
H = Hardness of glaze.

TABLE V—HARDNESS OF SOME TWO-COAT AND GREYWARE ENAMELS

	1	2	3	4	5	6	7	8	9	10
R	0.250	0.252	0.260	0.260	0.258	0.250	0.246	0.250	0.260	0.258
H	208	206	200	200	201	208	210	208	200	201

R = Radius of indentation in mm.
H = Hardness of glaze.

difference in hardness is to be noted. The greatest hardness is shown by the porcelain glazes and the lowest by the enamels. Attention must, however, be called to the fact that the results obtained for one and the same glaze are more or less discordant. The thickness of the glaze is evidently an important factor as well as the varying degree of firing which the specimens may have undergone. It cannot be expected that the results are more than rough approximations. They simply indicate the order of magnitude of the hardness. It is evident that the difficulties in the way of making exact determinations are very great. It is obvious that the chemical composition must have an important bearing on the hardness of the glazes, but no conclusive evidence can be deduced on this point.

One point of interest may be noted, however, namely, that an increase in the alumina content appears to bring about a distinct increase in the hardness of the glaze.

In the following summary table, the maximum and minimum hardness, together with the average hardness of each type of glaze, is given:

		Low	High	Total average
Whiteware Glaze No. 1	Cone 4	213	258	230
	Cone 6	249	300	279
Whiteware Glaze No. 2	Cone 4	248	296	270
	Cone 6	265	298	281
Porcelain Glaze	Cone 16	306	374	348
Two-Coat and Greyware Enamels		200	210	204

A STUDY OF SOME BOND CLAY MIXTURES[1]

By D. H. Fuller

ABSTRACT

In order to determine whether as good results could be obtained from mixtures of American clays as from the Gross Almerode clay in glass pot bodies, two American ball clays were combined in various proportions with two silicious American bond clays and compared with the Gross Almerode clay in bodies containing 50% grog. Physical properties and resistance to glass batch corrosion were determined. It was not found possible to duplicate the physical properties, especially the low water of plasticity and low drying shrinkage of the Gross Almerode body but several of the bodies gave better results as regards resistance to corrosion than the one containing the Gross Almerode clay. In general it was concluded that it is possible by blending American clays to produce a body equal or superior to the Gross Almerode body. More thorough heat treatment of pots or tank blocks in the arches and greater uniformity in temperature during the burning is required.

Introduction

The object of the present work was the study of combinations of aluminous with silicious bond clays, having in mind the utilization of such mixtures as refractories for the glass industry. It is a well-known fact that one of the best clays employed in this connection is the silicious material from Gross Almerode, which combines low drying and firing shrinkage with excellent plasticity and bonding power. An American clay having very similar properties is that from the mine of the Camden Clay and Coal Company, Lester, Arkansas. In addition there are available the more or less silicious pot clays from Missouri, the sandy clays from New Jersey and a considerable number of fire-clays, carrying much free silica, like those from the Ottawa, Ill., district; Mayfield, Ky.; Whitlock, Tenn.; and Warriors' Mark, Penna.

Further knowledge concerning the properties of mixtures of these silicious with the more aluminous bond clays would appear to be desirable, since it would seem from previous work that we must look to such combinations for our best results.

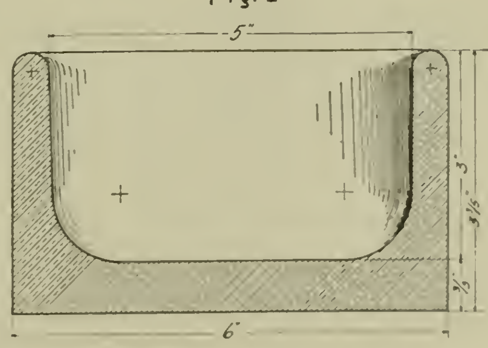
[1] Received September 8, 1921. Published by permission of the Director, Bureau of Standards.

The requirements for bodies of this type are good plasticity and bonding power, a fire shrinkage lower than that obtained by the exclusive use of ball clays, good resistance to corrosion by the glass, and sufficient rigidity under furnace conditions to avoid undue softening and consequent deformation. A pot body as silicious and open as the Gross Almerode is not desirable for all-round work, nor is one as aluminous as the dense plastic clays used in pottery work. A compromise between these two extremes would seem to offer the best solution. The objections to the German clay are its porous structure, which is vigorously though uniformly, attacked by the more fluid glasses, and its sensitiveness to sudden temperature changes. The drawbacks of the aluminous clays are their large firing shrinkage, and a tendency to deform at temperatures somewhat above those of normal operation.

Outline of Work

The experimental work consisted in making the usual determinations of the water of plasticity, drying shrinkage and modulus of rupture of the dried clays and bodies, porosity and shrinkage at different firing temperatures and modulus of rupture of the fired materials. The rate of firing was 20°C per hour. The trials were carried to cones 8 and 14. In addition, the resistance to the action of a corrosive glass was studied, using test crucibles five inches in diameter and three inches deep, shown in figure 1. These were fired to cone 12 and then filled with a raw mixture consisting of 100 parts of sand, 68 of soda ash, 20 of whiting and 2.8 of carbon,[1] and brought to a temperature of 1400°C where they were held for 12 hours. After

Fig. 1



[1] The original glass batch here employed contains salt cake. When this was replaced by soda-ash, the fact that carbon was no longer needed was overlooked.

breaking the cold specimens through the middle, the extent of the corrosion could be observed.

Four clays were introduced in this work, the ball clay No. 5 from Whitlock, Tenn.; the ball clay No. 4 from Mayfield, Ky.; the silicious bond clay from Lester, Ark.; and a saggar clay from Trenton, N. J., known as "Dogtown Clay." The physical properties of the first three clays have been reported upon in previous work,[1] in which they are given as numbers 13, 17 and 23. It may be stated here that the Dogtown Clay was not as silicious as had been expected.

The percentage chemical compositions of these clays were found to be as follows:

	Lester Ark.	Trenton N. J.	Whitlock Tenn.	Mayfield Ky.	Gross Almerode
Silica	72.05	54.13	47.70	53.22	73.08
Alumina	17.21	31.19	33.28	32.36	15.75
Ferric oxide	1.25	2.87	1.21	1.17	0.62
Titanium oxide	Not det.		Not det.		2.10
Lime	0.45	0.21	0.45	0.40	0.54
Magnesia	0.75	1.05	0.75	0.83	0.33
Potash	Not det.		Not det.		0.27
Soda	do.		do.		0.16
Loss on ignition	8.56	10.71	16.25	12.44	7.11

Mixtures were made of each aluminous clay with each of the silicious materials in the proportions of 4:1, 3:2, 2:3 and 1:4. Grog was also prepared consisting of 80 per cent Tennessee ball clay No. 5, 10 per cent of Georgia and 10 per cent of North Carolina kaolin, fired to cone 12. Bodies were made, using 50 per cent of each bond clay mixture to 50 per cent of grog. The crucibles for the slagging tests were made from these bodies and from an additional mixture consisting of 50 per cent of the above grog and 50 per cent of Gross Almerode pot clay. A series of bodies in which the above grog was mixed with each of the four bond clays in the ratio of 50:50 were submitted to the same tests as the mixtures of the blended clays with grog. The compositions of all the mixtures and bodies are given in table I.

[1] *Trans. Am. Ceram. Soc.* 19, 601 (1917).

TABLE I—COMPOSITIONS OF MIXTURES. PER CENT

No.	Tennessee ball	Kentucky ball	Arkansas	Trenton	Gross Almerode	Grog
A-1	80	..	20	..	..	..
A-2	60	..	40	..	..	..
A-3	40	..	60	..	..	..
A-4	20	..	80	..	..	..
B-1	..	80	20	..	..	..
B-2	..	60	40	..	..	..
B-3	..	40	60	..	..	..
B-4	..	20	80	..	..	..
C-1	80	..	..	20	..	..
C-2	60	..	..	40	..	..
C-3	40	..	..	60	..	..
C-4	20	..	..	80	..	..
D-1	..	80	..	20	..	..
D-2	..	60	..	40	..	..
D-3	..	40	..	60	..	..
D-4	..	20	..	80	..	..
E-1	40	..	10	..	..	50
E-2	30	..	20	..	..	50
E-3	20	..	30	..	..	50
E-4	10	..	40	..	..	50
E-5	..	40	10	..	..	50
E-6	..	30	20	..	..	50
E-7	..	20	30	..	..	50
E-8	..	10	40	..	..	50
E-9	40	..	..	10	..	50
E-10	30	..	..	20	..	50
E-11	20	..	..	30	..	50
E-12	10	..	..	40	..	50
E-13	..	40	..	10	..	50
E-14	..	30	..	20	..	50
E-15	..	20	..	30	..	50
E-16	..	10	..	40	..	50
E-17	50	..	..	..	..	50
E-18	..	50	..	..	..	50
E-19	..	..	50	..	..	50
E-20	..	..	..	50	..	50
E-21	..	..	..	..	50	50
F-1	..	..	..	..	100	..
F-2	100	..	..	..	..	..
F-3	..	100	..	..	..	..
F-4	..	..	100	..	..	..
F-5	..	..	..	100	..	..

Results

Physical Tests.—The results of the tests on the unfired clay and grog mixtures as well as those referring to their transverse strength, when fired to cone 12, are given in table II.

Table II—Results of Physical Tests upon Unfired and Fired Clays

No.	Water per cent	Volume drying shrinkage, per cent	No.	Modulus of rupture, pounds per square inch Dry state	Fired state
A-1	35.83	37.1	E-1	320	2252
A-2	38.49	33.15	E-2	343	2175
A-3	35.93	34.92	E-3	351	1787
A-4	33.35	35.38	E-4	339	2739
B-1	41.33	38.60	E-5	356	2132
B-2	37.38	38.70	E-6	355	2596
B-3	35.98	37.70	E-7	320	2003
B-4	32.25	35.66	E-8	284	1779
C-1	43.72	35.81	E-9	262	2583
C-2	43.88	32.08	E-10	246	2630
C-3	44.53	33.94	E-11	206	2549
C-4	44.07	33.00	E-12	270	2886
D-1	45.70	39.90	E-13	321	2790
D-2	43.90	34.91	E-14	268	2708
D-3	44.35	35.41	E-15	246	3064
D-4	45.73	35.35	E-16	221	2966
F-1	25.27	26.40	E-17	331	2625
			E-18	268	2466
			E-19	421	1473
			E-20	201	2827
			E-21	332	2210

It appears from these results that no combination of these clays possesses as low a water content or drying shrinkage as the Gross Almerode clay, 25.27 and 26.40 per cent, respectively, which, however, is not a fact of great importance for products that must contain from 50 to 60 per cent of grog.

A number of the grog mixtures in the dried state show a higher modulus of rupture than that containing the Gross Almerode clay, especially numbers A-2, A-3, B-1 and B-2. This is still more evident for the strengths in the fired state. The Arkansas clay by itself apparently does not possess a high strength, when fired, and any addition of Tennessee or Kentucky ball clay improves it, although not always in a consistent manner, since,

Fig. 2

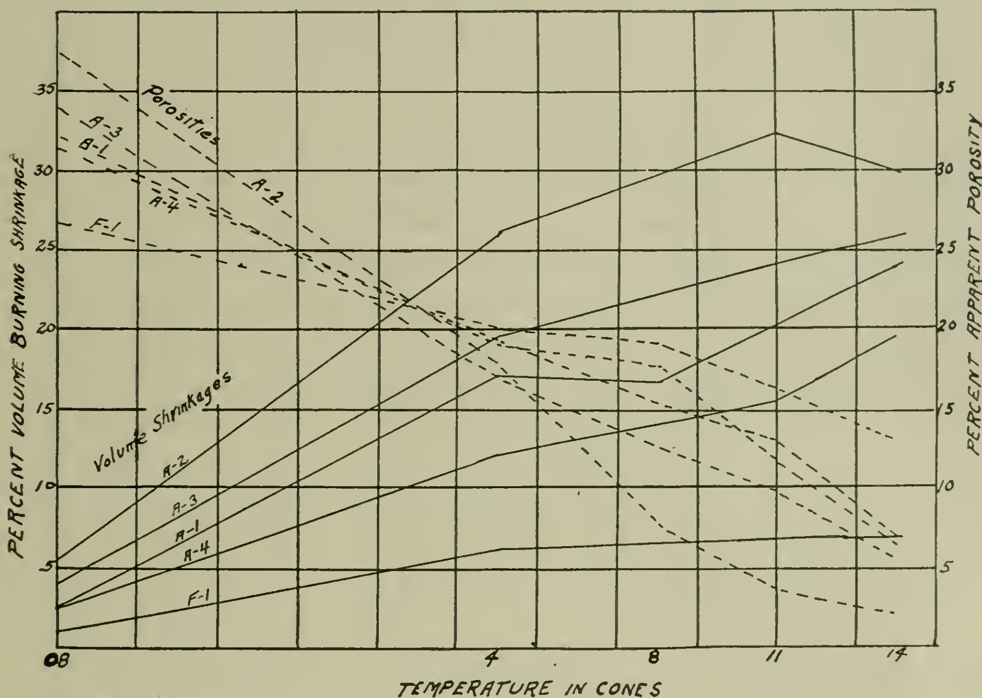
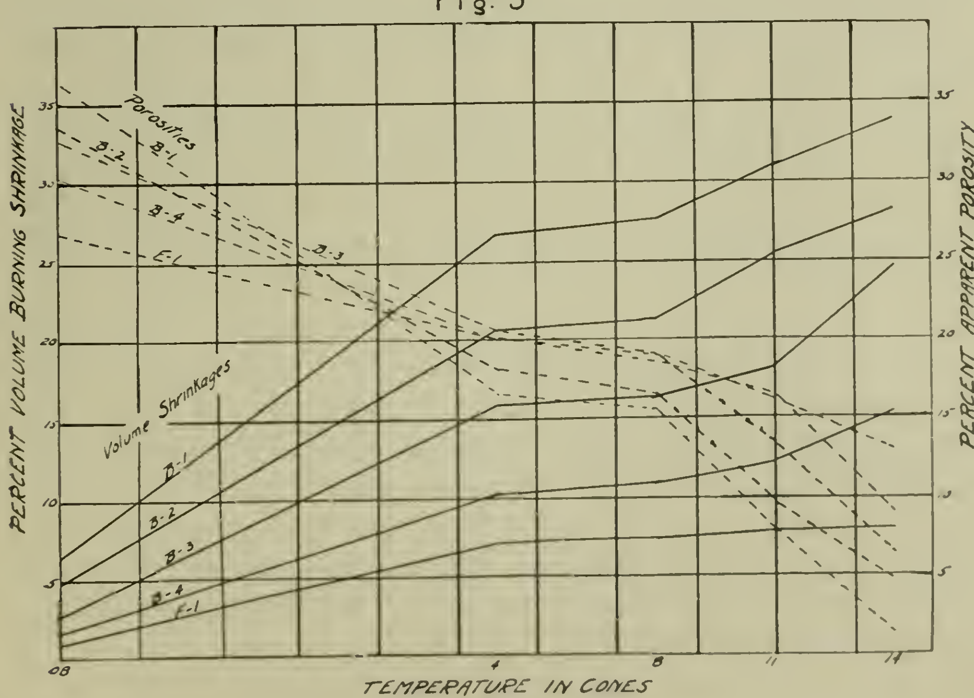

Porosities
A-3
B-1
A-2
A-4
F-1
Volume Shrinkages
A-2
A-3
A-1
A-4
F-1
PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
08
4
8
11
14
TEMPERATURE IN CONES

Fig. 3


Porosities
B-1
B-2
B-4
B-3
E-1
Volume Shrinkages
B-1
B-2
B-3
B-4
F-1
PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
08
4
8
11
14
TEMPERATURE IN CONES

for instance, a 1:4 mixture of Tennessee ball clay and Arkansas clay shows a higher modulus than with higher amounts of the former.

Firing Behavior.—The volume and porosity changes of the clay mixtures are best studied in groups. Let the combination of Tennessee and Arkansas clays be the first to be examined, using for this purpose the diagram of figure 2. From the fire shrinkage curves, figure 2, it is evident that the lowest and most gradual volume change is that of the Gross Almerode clay F-1. From previous work[1] we know that the Arkansas clay by itself undergoes an even lower fire contraction than the German clay, and we should expect the volume shrinkage of these mixtures to decrease with increasing amounts of the silicious clay. This is true, but the order in which they do so does not conform to the increase in Arkansas clay, since the highest shrinkage is shown by the proportion of 3 Tennessee to 2 silicious material. This discrepancy remains to be explained.

The highest proportion of silicious clay does, however, show the lowest contraction. This particular curve shows an accelerated volume change between the temperatures of cones 11 and 14. Practically the same facts are observed from the porosity curves of figure 2, from which we note also that the density of the clay mass of the mixtures is decidedly greater than that of the Gross Almerode clay.

Mixtures of Kentucky ball clay No. 4 and Arkansas clay, as will be observed from the shrinkage-temperature curves of figure 3, decrease regularly in contraction with the amount of the more silicious material, and a combination in the proportion of 4 Arkansas to 1 Kentucky clay approaches the Gross Almerode clay quite closely. It is not at all unlikely that the mixture B-3, in the proportion of 2 Kentucky to 3 Arkansas clay would be satisfactory all around and overcome the defects of both types of clay. The minimum pre-firing pot arch temperature of this set of combination appears to be cone 4. The porosity and temperature curves, figure 3, give us similar information showing very close agreement in behavior between the mixture B-4 and the Gross Almerode clay and pointing again to the very promising characteristics of mixture B-3.

[1] *Trans. Am. Ceram. Soc.*, 19, 601 (1917).

With reference to the admixture of the two ball clays with the New Jersey saggar clay, the results obtained show that the choice of the latter material was not a happy one, as it is not as high in silica as would be desirable for this purpose.

This is shown in the curves of figure 4, expressing the temperature-shrinkage relation of blends between the Tennessee and New Jersey clays. The reduction in fire contraction is not great enough to justify the preparation of such mixtures. A similar conclusion must be drawn from the temperature-porosity relation, figure 4, though here C-4 shows up to somewhat better advantage. While in the shrinkage curves the changes between the different proportions of the saggar clay are consistent with the amounts introduced, there is noted an overlapping of the curves at cone 8, which is resolved again into the regular order at cone 11. The dry strength of these mixtures (see E-9, E-10, E-11 and E-12, table II), when made up with 50 per cent of grog, is also below the average.

The results obtained with mixtures of the Kentucky ball and New Jersey sagger clay are similar to those shown in figure 5 and hence need no separate discussion. No significant changes are to be observed, even with larger addition of the saggar clay, and no material beneficial effect is indicated.

Corrosion.—In studying the resistance to corrosion of the different clays and clay mixtures, the Gross Almerode clay, or No. 21, has been used as the basis of comparison. The results follow:

E-1.—Body structure quite dense, white color. Less attack by glass than G. A.; color of glass better than in G. A. pot.

E-2.—Structure more open and attacked by glass like G. A. body, but color much lighter.

E-3.—Glass attacked as with G. A. body, but color much lighter; structure very similar to G. A. body, but somewhat more dense.

E-4.—Very close to G. A. body though of lighter color; slightly denser than G. A. body.

E-5.—Body more porous than G. A. body but of much lighter color. Glass attack very slight.

Fig. 4

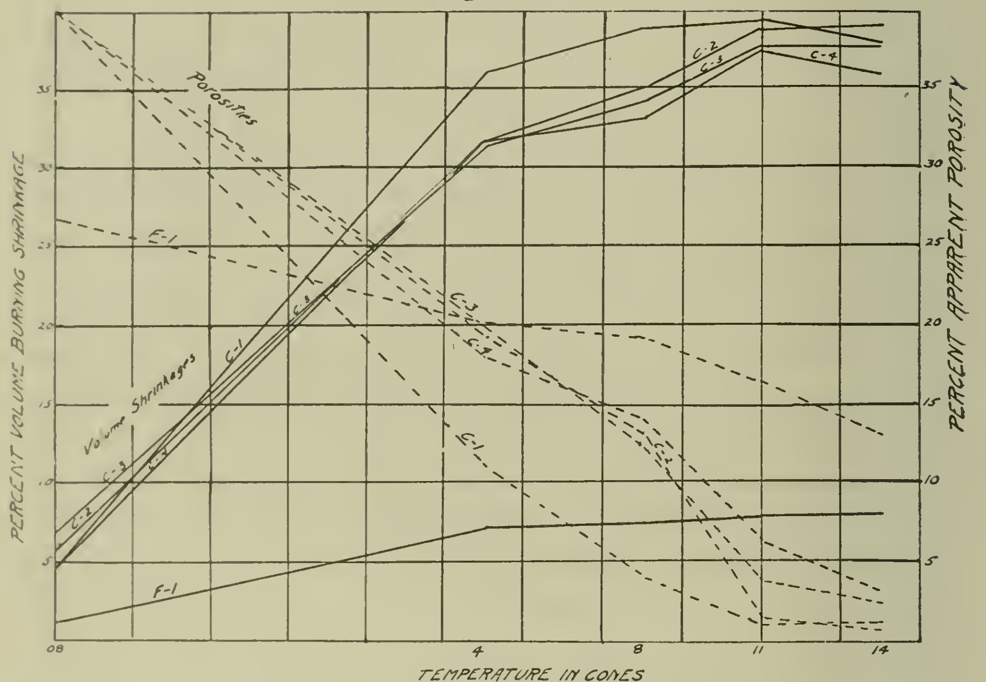

Porosities
Volume Shrinkages
PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
TEMPERATURE IN CONES
08
4
8
11
14
C-1
C-2
C-3
C-4
F-1

Fig. 5

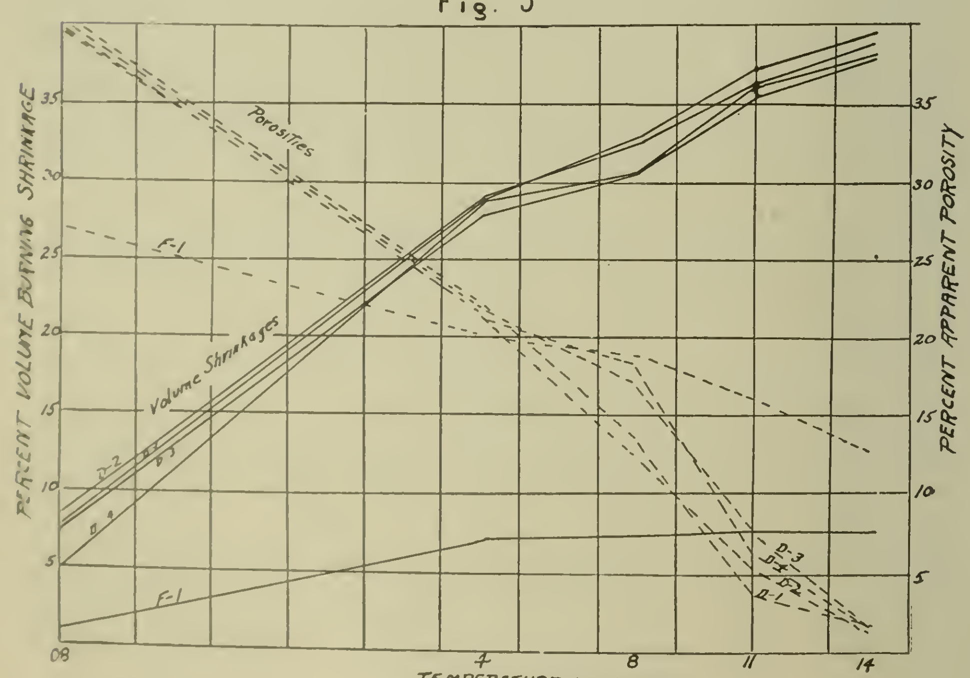

Porosities
Volume Shrinkages
PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
TEMPERATURE IN CONES
08
4
8
11
14
F-1
D-1
D-2
D-3
D-4

Fig. 6

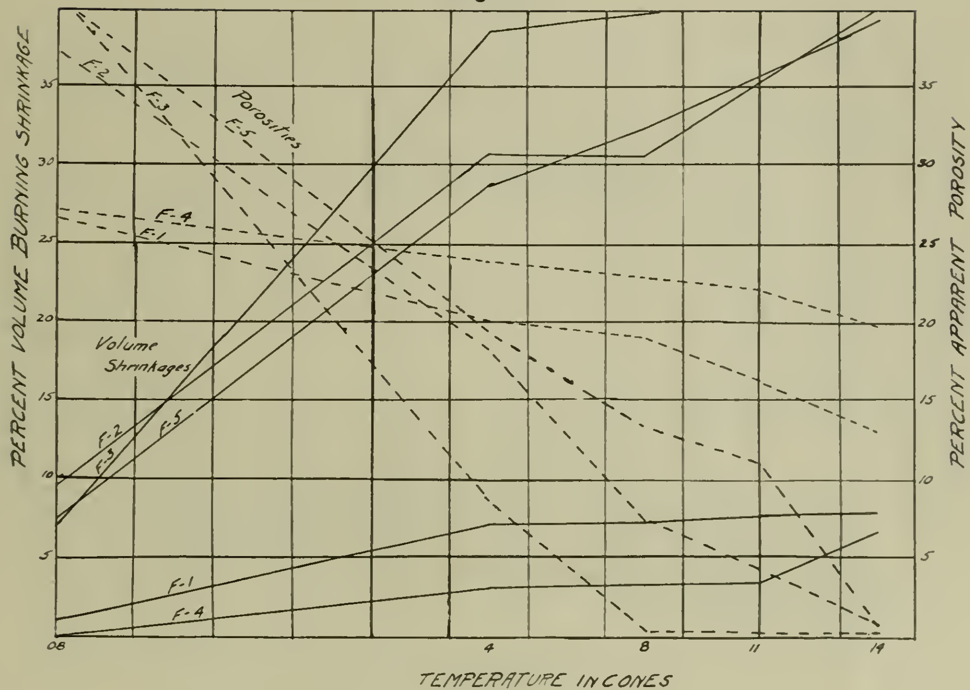

PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
Porosities
E-2
E-3
E-5
E-4
E-1
Volume Shrinkages
F-2
F-3
F-5
F-1
F-4
TEMPERATURE IN CONES

Fig. 7

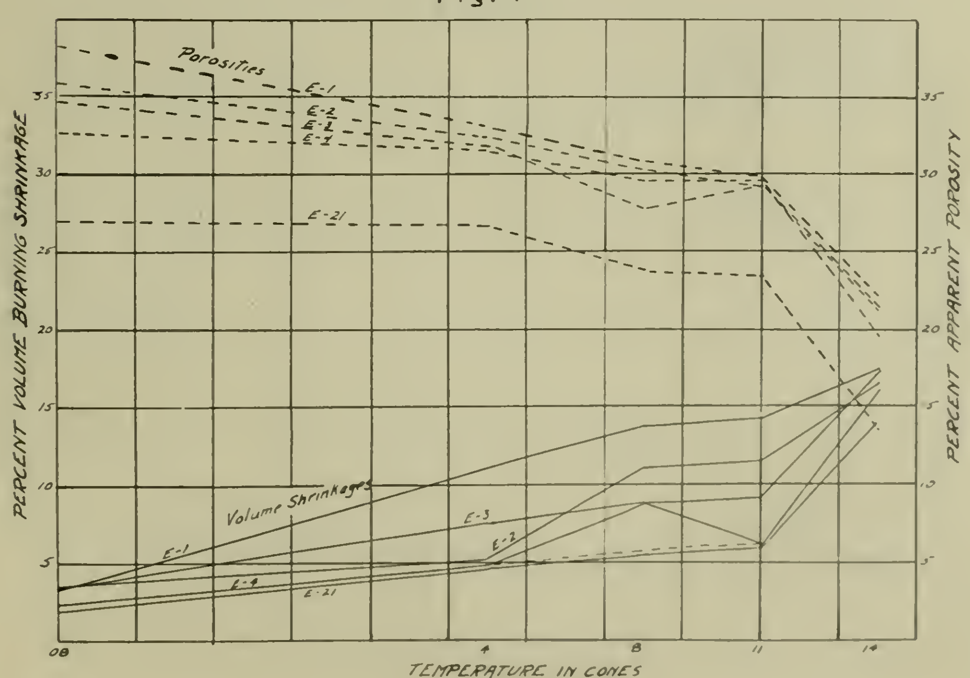

PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
Porosities
E-1
E-21
Volume Shrinkages
E-3
E-2
E-4
TEMPERATURE IN CONES

Fig. 8

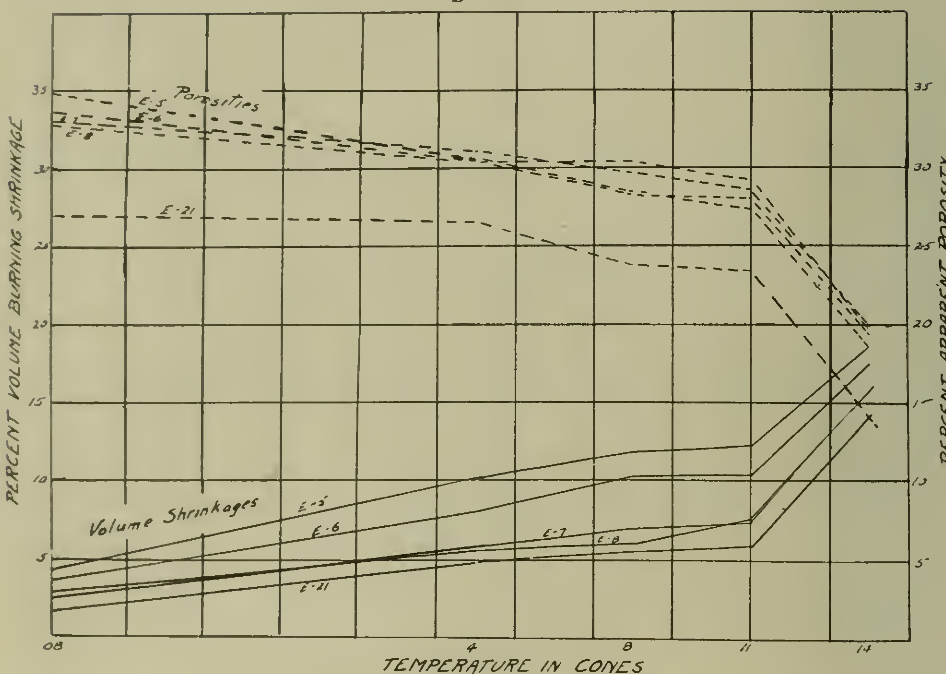

Porosities
E-5
E-6
E-8
E-21
Volume Shrinkages
E-5
E-6
E-7
E-8
E-21
PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
08
4
8
11
14
TEMPERATURE IN CONES

Fig. 9

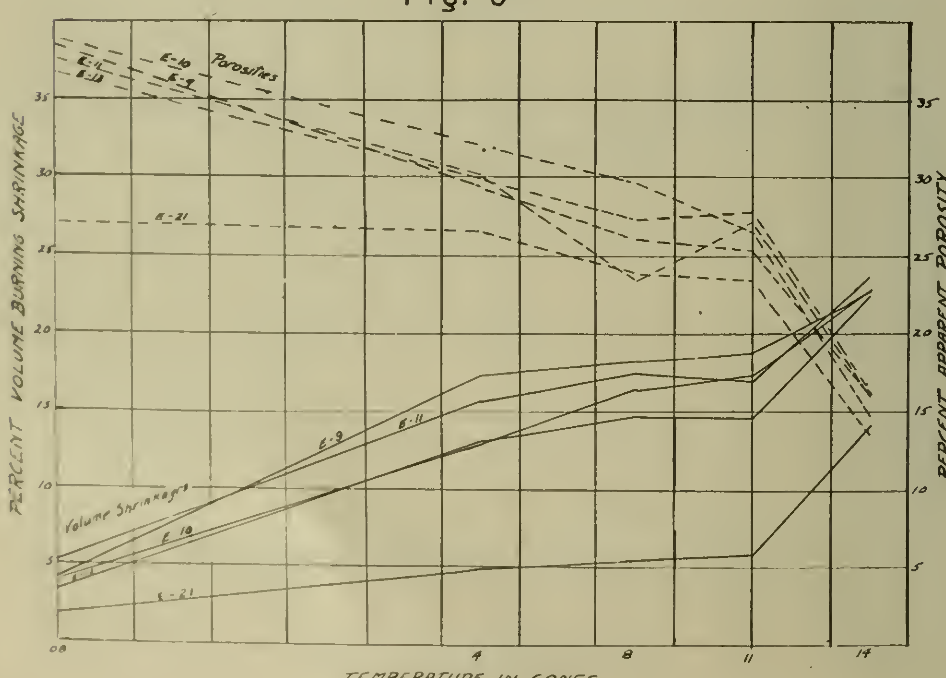

E-10
Porosities
E-11
E-13
E-9
E-21
E-9
E-11
Volume Shrinkages
E 10
E-21
PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
08
4
8
11
14
TEMPERATURE IN CONES

Fig. 10

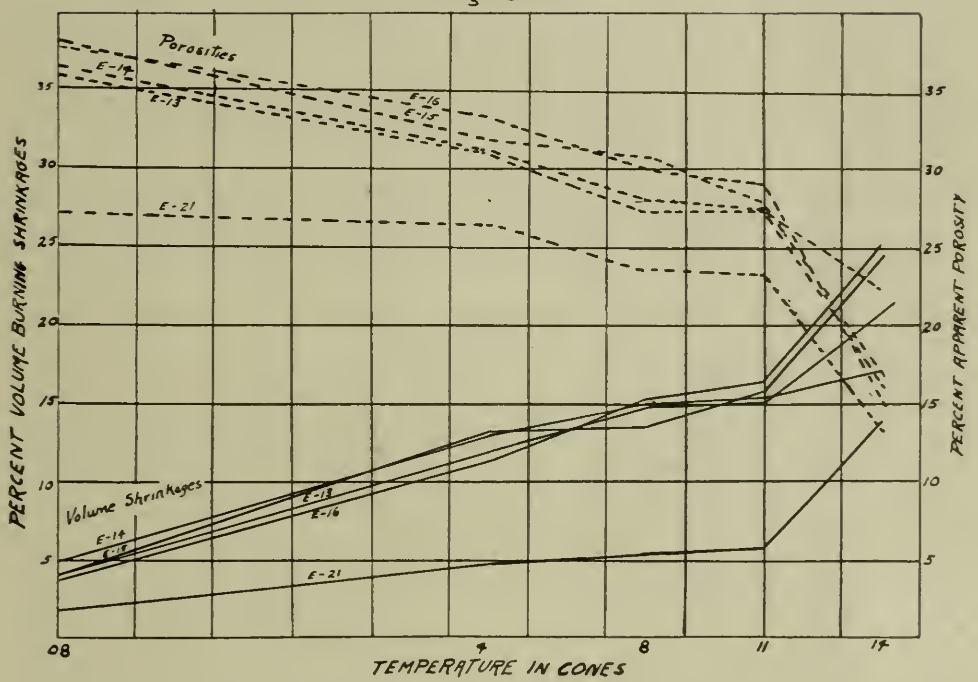
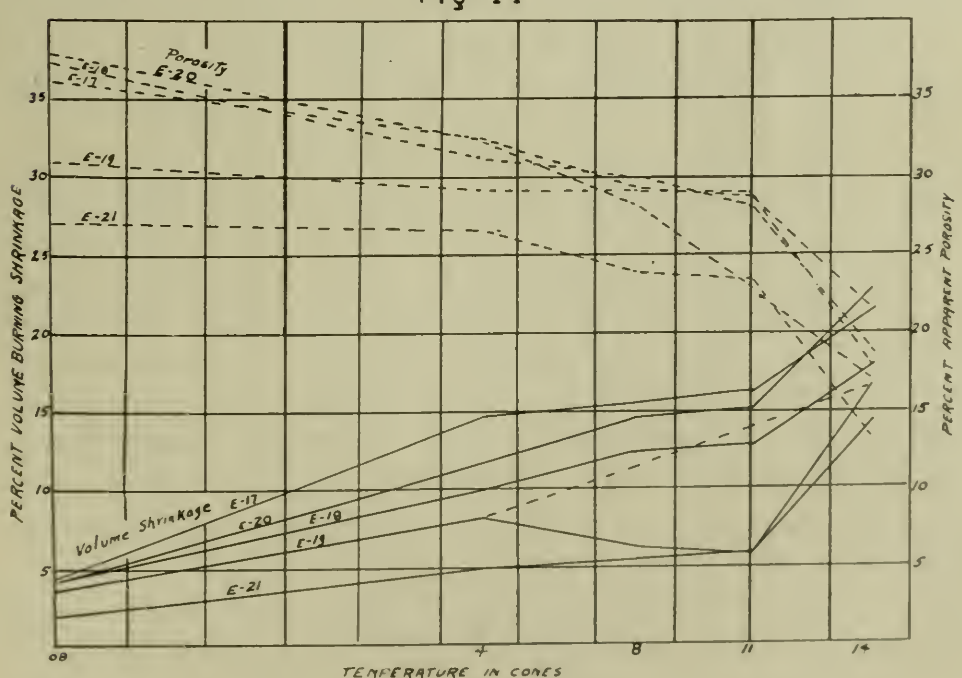

Porosities
E-14
E-13
E-16
E-15
E-21
Volume Shrinkages
E-14
E-13
E-16
E-21
PERCENT VOLUME BURNING SHRINKAGES
PERCENT APPARENT POROSITY
08
4
8
11
14
TEMPERATURE IN CONES

Fig 11


Porosity
E-20
E-17
E-19
E-21
Volume Shrinkage
E-17
E-20
E-18
E-19
E-21
PERCENT VOLUME BURNING SHRINKAGE
PERCENT APPARENT POROSITY
08
4
8
11
14
TEMPERATURE IN CONES

E-6.—Same as E-5, but somewhat more porous. White layer between glass and clay, somewhat more pronounced though attack has been slight.

E-7.—Very similar to G. A. body, both as regards glass attack and density.

E-8.—Again similar to G. A. body but showing somewhat less attack by glass than corresponding composition with Tennessee clay E-4.

E-9.—Somewhat heavier glass attack than G. A. body, but of much lighter color.

E-10.—Much more glass attack than G. A. body.

E-11.—Glass attack still more pronounced and white layer between glass and clay, more than in G. A. body.

E-12.—Glass attack very pronounced.

E-13.—Glass attack heavier than in G. A. body.

E-14.—Glass attack heavier than in G. A. body but not as much as in E-13.

E-15.—Glass attack heavier than in G. A. body; structure rough.

E-16.—Glass attack quite heavy and glass colored dark green by iron.

E-17.—Glass attack heavier than with G. A. body, but color of glass much lighter; structure quite porous.

E-18.—Glass attack slightly more than in G. A. body, but color much lighter. Body structure fairly dense.

E-19.—Glass attack slightly heavier than in G. A. body.

E-20.—Glass attack quite severe and glass a very dark color.

It appears from the corrosion test that the difference between the American clay bodies and the G. A. clay is not very marked except in the case of the New Jersey saggar clay. It would appear from this that the primary advantage of the G. A. clay lies not so much in its resistance to corrosion, as in its low volume changes upon firing and its rigidity at furnace temperatures and under load condition. It would appear, therefore, that from the standpoint of resistance to corrosion, our American clays are at least equal or superior to the G. A. clay. The conclusion must be reached therefore, that we can not only expect to reproduce a type of clay equivalent to the G. A. clay, but that we can obtain bodies superior to it. The latter condition can

be reached with still greater certainty by increasing the previous heat treatment of the pots or tank blocks, that is, by raising the arch temperatures and striving for greater uniformity in temperature during this preliminary burning. It is expected that a more comprehensive study of the resistance to corrosion will be made, employing glass batches attacking the structure more vigorously and discriminating more sharply between the different materials.

Discussion

Geo. A. Loomis: This is a very interesting and valuable paper and the data presented represent a great deal of work.

In regard to the corrosion test, I believe that twelve hours is much too short a time for such a test to differentiate sufficiently between the different mixtures. I believe it is imperative to run such a test at least twenty-four hours at the final temperature to get a proper differentiation. I realize that in isolated laboratories it is not always possible to have compressed air continuously for the burners to maintain the high temperature for this length of time. That is no doubt the reason that the time was not extended in this case. Extending the time for the test is, however, much to be preferred to using a more corrosive glass than that used.

C. W. Berry: Mr. Fuller's paper should prove of value to the Glass manufacturer and also the pot manufacturer, in that it shows the existence of satisfactory American clays. Under the present methods of arching pots, the silicious mixture generally gives the best service, although with proper temperatures in the arches, the aluminous type of pot is satisfactory.

During the past year the writer has witnessed a number of tests made on an aluminous type of pot. This mixture showed great resistance to corrosion, but owing to the low temperatures employed in the arches considerable difficulty was experienced after pots were placed in the furnaces.

At one plant the pots were heated to 2700° F. in the arches and the pots gave excellent service. This shows the need of improved arches and higher temperatures.

POROSITY: I. PURPOSE OF THE INVESTIGATION II. POROSITY AND THE MECHANISM OF ABSORPTION[1]

By Edward W. Washburn

ABSTRACT

Significance of porosity.—This is briefly outlined.

Standard reference method.—The requirements of an *engineering* testing method are simplicity, rapidity and convenience with no more accuracy than practical considerations justify. There should, however, be also available a *standard reference method,* that is, a laboratory method where accuracy is the main requirement.

Types of pores.—Six types of pores are described and the *process of absorption* under various conditions is analyzed.

Definitions.—Definitions are proposed for the terms, *permeability, penetrability, absorptivity, porosity, bulk density, closed-pore space* and "*cracks*" and "*holes*," and methods of measurement are suggested.

Introduction

1. Purpose of the Investigation.—The critical examination of the methods of testing which are employed for securing those data which characterize and measure the qualities or behavior of the raw materials or the products of any branch of technology is justly regarded as one of the important fields of research of every applied science. In studying and interpreting the behavior of ceramic products during drying and firing, the determination of the porosity and of the changes which it undergoes, especially during the firing operation, is an important factor. Porosity also has an important bearing upon the strength of the body, upon its behavior as an adsorbent, and upon its resistance to weathering, shock, abrasion, erosion, slagging, temperature strains, discoloring agents, efflorescence, chemical attack by gases and liquids, and the destructive action of fungus growths,[2] as well as upon the values of certain physical proper-

[1] Received May 1, 1921.

[2] Scott, James, "Tile Fungus," *Brit. Clayworker,* **18,** 138 (1920).

ties of the body such as its bulk density, its strength as a dielectric, its permeability, and its thermal and electrical conductivities.

An examination of the literature dealing with this subject reveals the fact that no adequate systematic study seems ever to have been made of the nature and magnitude of the errors involved in determining porosity by the commonly used methods of absorption. The present series of investigations was undertaken for the purpose of throwing some light upon these questions and of evolving, if possible, a procedure for porosity measurements which should meet the requirements of a *standard reference method.*

In order that the purpose of the investigation may be clearly understood a brief explanation of term *standard reference method* and of its relation to what may be termed practical or engineering standard methods is desirable. The important characteristics of an *engineering* testing method are simplicity, rapidity, and convenience. The degree of accuracy attainable in the method need only be that demanded or justified by the nature of the materials to be tested and the purpose of the information sought. A higher degree of accuracy than this is undesirable, if its attainment involves an essential sacrifice of rapidity or convenience. Thus the measurement of porosity by the comparatively rough and inexact method of soaking in water might give all the information necessary (or all the information which the variability of the material under examination would justify) in the case of common brick for the purposes of the structural engineer, although the same method would obviously be quite useless if applied, for example, to a ball mill body or to a piece of electrical porcelain.

In order to ascertain the accuracy of a proposed engineering method and thus to form an opinion of its availability for a given class of materials, it is desirable, in many instances, to have available also what we have termed a *standard reference method*, that is, a laboratory method in which *accuracy* is the principal requirement and rapidity and convenience, while important, are only secondary. Such a method should preferably be applicable to as great a variety of materials as possible. With this

purpose in mind we shall, in the subsequent papers of this series, proceed to examine the various methods which have been proposed and used for determining porosity, in order to ascertain the nature and magnitudes of the errors which they involve and, in the light of the information thus obtained, to devise an appropriate standard reference method. The remainder of the present paper will be devoted to an analysis of the mechanism of absorption and to proposed definitions of terms.

II. Porosity and the Mechanism of Absorption

2. **The Factors Involved.**—Before proceeding to an examination of the methods of measuring porosity and to the consideration of the problems connected with the formulation of a "standard reference method" it is desirable to have a clear concept of the exact nature of the quantity which such a method is intended to measure and of its relation to the associated properties of closed-pore space, permeability, penetrability, absorptivity on immersion, bulk density, true density, cracks, and holes.

This subject may perhaps be best approached by attempting to form a mental picture of the various types of pores which may exist in a body.

3. **Types of Pores.**—In figure 1 are depicted a variety of types of pores which one can imagine as possible forms produced during the firing of a ceramic body. For convenience in reference, the types shown may be designated as follows:

(1) THE CLOSED OR BUBBLE PORE, *a*.

(2) THE CHANNEL PORE.—These are of two principal types, the vertical, b_1, and the horizontal, b_2, with various intermediate inclined forms. Belonging to this type are also the connecting pores which exist between the particles of a mass made up of grains in simple contact with one another, a simple example of which is a heap of sand grains. The channel pores connect with one another so as to form a passage way through the body.

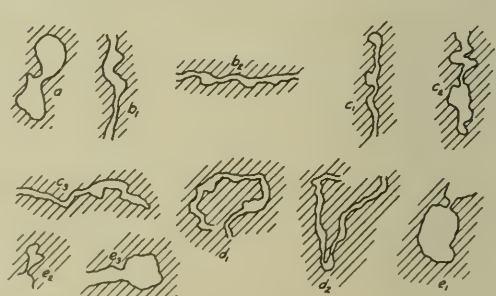


FIG. 1.—Types of pores.

(3) THE BLIND-ALLEY PORE.—These are of three principal types, the upright, c_1, the inverted, c_2, and the horizontal, c_3, with the various intermediate inclined forms.

(4) THE LOOP PORE.—These may be either upright, d_1, inverted, d_2, horizontal, or of an intermediate inclined type.

(5) THE POCKET PORE.—These are fairly large pores with short necks. The necks may be wide as in e_3, narrow as in e_1, and e_2, or so narrow as to cause the pocket to approach the closed-pore type in behavior.

(6) THE MICROPORE.—This type of pore, which is not represented in the figure, includes all pores with diameters so small that they can not be filled by a liquid in any reasonable time of soaking. The diameters of many of them approach molecular dimensions and the type itself gradually merges into the intermolecular pore space. There is probably in many cases also no sharp division between this type and the larger pores whose volume is included in the measured pore volume of the material.

A great variety of combinations and modifications of the above types are obviously possible, and even with regard to the pictured forms shown in Fig. 1, it must be remembered that they actually exist in three dimensions and not in two as represented. The types shown will, however, suffice to make clear the various possible types of behavior.

4. Permeability.—It seems desirable to restrict the use of this term to represent the readiness with which the body permits a fluid to flow through it from one side to the other. The permeability may be measured by the rate at which some standard fluid, either a gas or a liquid, flows through unit area and unit thickness of the body under some specified pressure head From this definition, it is evident that only the channel pores are active in determining the permeability of a body, with the possible exception of some of the loop pores which might happen to be so located with reference to the direction of flow as to function to a slight extent as channel pores. The permeability will, therefore, be determined by the number and dimensions of the channel pores and by their locations with respect to the line of flow.[3]

[3] For examples of the measurement of the permeability of refractory materials see Wologdine, S., *Electrochem. Met. Ind.*, **7**, 1433 (1909).

5. Penetrability.—In connection with determining the resistance of a body to weathering and to the action of slagging and discoloring agents, it has been proposed to measure a property which may be appropriately designated as the penetrability of the body. As a *physical* quantity, it may be qualitatively defined as the ease with which a liquid is drawn into the pores of the body by capillary action, without attendant chemical action between the body and the liquid.

A quantitative definition is possible only when agreement is reached as to the method to be used in measuring the property in question. It might, for example, be measured in the following way: By the amount of a standard liquid which, in a stated time, a standard test piece will absorb, at a stated temperature, when a stated surface of the piece, in a determined position (horizontal or vertical, and, if horizontal, then a lower not an upper surface), is kept in contact with the liquid, and the air surrounding the test piece is kept saturated.

The only class of pores which could be completely filled by capillary forces alone would be the channel pores. All of the other classes except the closed pores would, however, be *partially* filled. Not all of the channel pores would necessarily be completely filled, however, since the height of the capillary rise in a vertical channel pore is limited by its diameter.

6. Absorptivity on Complete Immersion.—The amount of liquid absorbed by a test piece, completely immersed with all of its surface pores open, would be determined by a combination of its penetrability, its permeability, and its porosity. The liquid would flow upward through, and eventually completely fill, the channel pores because of the pressure difference on the upper and lower faces of the piece. It would be drawn in laterally by the capillary forces, and these forces would eventually *partially* fill the remaining types of pores except the closed pores. The air entrapped in the partially filled pores would then dissolve slowly in the liquid and diffuse still more slowly outward and eventually escape, thus permitting these pores after a long period of time to become completely filled with the liquid. The method of simple immersion (*i. e.*, without boiling)

whether *in vacuo* or not, does not,[4] therefore, measure any accurately definable physical property of the material, unless the immersion is continued for the *very* long period necessary to fill the pores by the slow process of solution and diffusion of the air, in which case the method measures the porosity.[5] The removal of the air from a pocket pore with a narrow opening would be especially slow by this process. The absorptivity on immersion will thus be a function of the time of immersion and of the surface tension and viscosity of the immersion liquid.

7. Porosity.—By the term porosity we shall understand the open-pore porosity. It differs from the preceding properties in that it includes the total volume of all types of pores except part of the micro-pores and except those closed pores having walls of sufficient strength to withstand the treatment to which the test piece is subjected during the porosity measurement. Any method employed for measuring it must be one which will insure the complete filling of all these pores by the fluid employed.

8. Bulk Density and True Density.—The term "bulk density" (called also "apparent density") may be conveniently employed to designate the ratio of the mass of the test piece to its volume. It is conveniently and accurately determined by weighing the completely saturated test piece suspended in any suitable liquid or by means of a volumeter method using mercury as a liquid.

The true density is most conveniently measured by the pycnometer method applied to the finely powdered material. With suitable precautions, which have already been carefully worked

[4] Unless the vacuum is high enough to remove substantially all the air. The use of a moderate vacuum would have no practical value, since it would not hasten the slow stage of the absorption process.

[5] In spite of the fact that the result obtained varies with the time of immersion it is nevertheless conceivable that by specifying a standard immersion procedure, the measurement of absorptivity under these conditions might give an excellent indication of the probable resistance of the body to freezing and thawing of absorbed water, for example. In other words a testing method might give a result which would indicate the general behavior of a material under certain conditions, even though it did not measure any quantitatively definable physical property, in the strict sense of the term.

out,[6] the true density can, if desired, be determined with a precision of better than 0.1 per cent, provided closed pores smaller than the particles of the powder are not present.

9. Closed-Pore Space.—This is calculated from the true density, the bulk density, and the porosity. When so calculated it includes only those closed pores whose walls are strong enough to withstand the temperature and pressure differences which are produced by the procedure employed in measuring the porosity. In practice it would also, of course, include part of any open pores which did not become completely filled with the absorption liquid. This method of determining closed-pore space is, of course, reliable only if the fineness of the grinding employed in connection with the true-density measurement is sufficient to rupture all the closed pores.

10. Cracks and Holes.—Cracks and holes are spaces in a body so large that they should not be counted in, in computing its porosity and the method used for measuring porosity should, if possible, be one which can be depended upon to reject such spaces. Now the maximum sized space which would be classed as a pore obviously varies with the nature of the ware. Thus most of the actual pores of a "non-pareil" insulating brick are so large that if they were found in a piece of porcelain they would be classed as holes.

It is obvious, therefore, that a standard reference method for measuring porosity should be of such a character that the maximum size of opening to be included as part of the pore space should be under the control of the operator. Methods of accomplishing this will be discussed later.

(*To be continued*)

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[6] See, for example, Johnston, J., and Adams, L. H., *Jour. Amer. Chem. Soc.*, **34**, 572 (1912); cf. Cude and Hullett, *Ibid.*, **42**, 400 (1920).

DISCOLORATION OF WHITEWARE FIRED IN CARBORUNDUM SAGGARS[1]

By H. Spurrier

ABSTRACT

The author advances the hypothesis that iron carbonyl, formed by reaction between CO and iron present in the carborundum saggars, condenses in the central portion of the bung, trickles down over the ware and is later decomposed, giving iron and free carbon, which are absorbed and color the ware. Laboratory experiments completely confirmed this hypothesis.

Many of those who have used carborundum saggars for whiteware have experienced annoyance from discoloration of the ware. The manner in which this discoloration takes place presents some peculiarities which on careful examination furnish the clue to the cause of the trouble.

It is not uncommon to find a saggar of spark plug blanks uncolored or only slightly colored on the outer rings, but with a central portion exhibiting a rather beautiful, but very undesirable range of color from dove gray to dark battleship gray, or even nearly black, on the upper portion; while the lower portion shows a rust red and no mottle. The uppermost and lowermost saggars of a bung never show these characteristics to nearly the extent exhibited by the saggars in between.

On inspecting some of the discolored ware it will be noticed that the plugs in many cases appear to have some ferruginous liquid spattered upon them, which has trickled down the nearly straight sides to a projecting ring or a recess, there to gradually flow around the ring till a sufficient accumulation forces it to find a channel by which to flow still further down to the bottom of the plug where it again accumulates. Firing will subsequently oxidize the ferruginous liquid and leave a path, rust red in color, and fluxed permanently into the glaze. The bore hole of these plugs is also colored but of a reddish fawn evidently the product of the gray and the incompletely oxidized iron.

[1] Received March 11, 1921

These appearances are so suggestive as to unavoidably lead to the hypothesis that the carborundum saggars are responsible for the discoloration and one naturally begins to speculate as to some rationale that will fit the observed phenomena to the speculation.

It is well-known that carbon monoxide at about 70–80 °C will, in the presence of finely divided iron, produce volatile carbonyls of which two are well-known: Tetracarbonyl, $Fe(CO)_4$, and pentacarbonyl, $Fe(CO)_5$; that at higher temperatures these carbonyls are decomposed into iron and carbon monoxide,[1] the finely divided iron quickly oxidizing if circumstances permit.[2]

Supposing this to be taking place, how does it fit the evidence? Assuming the kiln placed and firing commenced, the temperature rises to the necessary 80 °C, the top and bottom saggars of the bungs receive heat from the sides and from the top and bottom respectively also, and the intermediate bungs are heated mainly from the sides, the centers remaining relatively cool for a period.

We have therefore the condition that explains the ring of nearly uncolored plugs in the intermediate saggars, which does not appear or is much less pronounced in the top and bottom, saggars. The intermediate saggars rise to or above 80 °C on the outside, the centres remaining cooler. The formation of iron carbonyl (assuming of course the presence of the necessary metallic iron and carbon monoxide in the system) commences, and it is driven toward the cooler portion which is at the centre. Here the carbonyl vapors, probably assisted by whatever plus pressure may exist,[3] tend to condense, and the liquid gradually accumulating trickles down the plugs producing the lines of flow previously described. As the temperature at the center rises to the decomposition point of the iron carbonyl, it must be decomposed here, as there is no cooler point for its condensation. The iron is left as a residue and some of the carbon is

[1] This is also true of nickel and forms the basis of Ludwig Mond's process for the production of metallic nickel.

[2] The red discoloration found on steatite gas tips is caused by the breakdown of iron carbonyl (formed from the carbon monoxide) upon reaching the heat of the gas tip.

[3] The formation of iron carbonyls is much assisted by pressure which moreover stabilizes them somewhat against decomposition by heat.

absorbed, producing the graduation of the gray shades. As the outer rings of plugs in the saggars are heated at the start the above-mentioned reaction is here largely avoided. The iron carbonyl does not condense on them and the ware consequently remains white or much lighter in color.

So much for the thermo-chemical behavior; but does the iron exist in the carborundum saggar? And if so, would carbonyl be formed under the conditions? And if formed would it have the effect noted?

The presence of finely divided iron in the carborundum saggars may be proved by crushing portions of new saggars in a Wedgwood mortar and subjecting them to the action of an electromagnet, the poles of which are protected with a thin paper sheath. On interruption of the current the metal particles are dropped at once. Magnetic separation is carried on till the metal particles are quite clean and free from foreign matter. The identity of the magnetic concentrate thus cleaned has been established by chemical tests (nearly complete solubility in hydrochloric acid and so forth) and by microscope observation.

The existence of carbon monoxide needs no demonstration because its presence is unavoidable. Consequently the necessary conditions exist.

It now remains to prove that the saggar material heated gently in the presence of carbon monoxide will actually yield iron carbonyl and that iron carbonyl will produce the effect noted. The procedure is as follows. Partly fill a quartz conbustion tube with the saggar material crushed as before, then insert a plug of glass wool and charge a portion of the tube with granules of charcoal. The portion charged with carborundum can be kept at the desired temperature by packing filter paper around it and allowing warm water to continually flow over it. Heat the portion containing the charcoal to full redness and pass through a gentle stream of dried and purified carbon dioxide. The familiar reaction of the reduction of carbon dioxide to carbon monoxide takes place.

The exit end of the quartz tube should be furnished with a small condenser kept below 70°C with a cooling mixture if the hydrant water is too warm to use. After a considerable time

the above experimental procedure yielded a very small amount of liquid which, on heating in a tube under a slight pressure, decomposed, leaving a small residue. The issuing gas reacted with palladium paper indicating carbon monoxide. On breaking the tube the residue was found by chemical and microscopic tests to be ferruginous.

The next step was to actually produce the discolored body by the above means, and, owing to the minute quantity of iron carbonyl produced in the previous test, it was necessary to use a somewhat different method. Accordingly the tube was set up as before, but without the small condenser, a stopper and educt tube taking its place. A small piece of glazed and unfired ware was placed between the carborundum and the stopper, a space of about 12 inches. The portion of the tube holding the charcoal was well heated, no carbon dioxide being admitted. The tube was then evacuated, the portion of the tube charged with carborundum being kept between 70–80°C. The carbon dioxide was then very slowly admitted till the carbon dioxide generator showed a slight pressure, evacuation of course being stopped. The portion holding the clay ware was next gradually heated, heating being continued with a large blast lamp urged to the limit. After two hours the heating was discontinued and the apparatus allowed to cool. When the test piece was taken out, although underburned, it showed the characteristic discoloration, the gray color was pronounced, the mottling of gray and ruddy color, slight, but in evidence. Similar pieces fired in the same tube without the carborundum showed no discoloration and the results compel the only possible conclusion, that the discoloration is due to the formation of iron carbonyl, which is made possible by the free iron in the crushed carborundum.

Carborundum carefully boiled for a long time with hydrochloric acid washed and dried does not, on treating as above, result in discolored ware in the quartz tube.

Although the writer has not personally proved the existence of free carbon in carborundum, he understands that it may sometimes be present and in such cases the formation of iron carbonyl would be much facilitated.

DETROIT, MICH

NOTE ON THE DISSOCIATION OF FERRIC OXIDE DISSOLVED IN GLASS AND ITS RELATION TO THE COLOR OF IRON-BEARING GLASSES.[1]

By J. C. Hostetter and H. S. Roberts

ABSTRACT

It is shown that above 1300°C, Fe_2O_3 is dissociated appreciably with the evolution of O_2 and the formation of the corresponding quantities of FeO. The same reaction is found to take place in glasses. The following percentages of Fe as FeO based on the total Fe present illustrate the extent of this dissociation in glasses. Diopside glass ($CaSiO_3.MgSiO_3$) 1400° C, 20%; 1500° C, 30%; 1600° C, 45%. 0.6 K_2O—0.4 CaO—$2SiO_2$, 1310° C, 5.8%; 1555° C, 10.1%. 0.3 K_2O—$0.3Na_2O$—0.4 CaO—$2SiO_2$, 1020° C, 4.1%. In the two latter glasses a dissociation of 10% produced a bright green color: the glass with a dissociation of 4.1% was yellow. Iron compounds in a glass may therefore be "reduced" by heating to a high temperature under oxidizing conditions. The intensity of the color due to iron is closely related to the composition of the glass, but data on this point are not sufficiently complete to warrant generalizations.

General Effects of Iron in Glass

Iron, in some form, is present as an impurity in every raw material used in the manufacture of optical glass. When the quality of raw materials and pots is otherwise satisfactory, the color developed by iron in glass is the most important factor in lowering transmission. The actual iron content of precision optical glass varies from 0.01 per cent to 0.05 per cent (expressed as Fe_2O_3) even when made from the purest raw materials obtainable and melted in resistant pots of low iron content. The absorption of light caused by even these small amounts of iron is significant and easily measurable, but the relation between total transmission and iron content is obscured somewhat because of the two co-existing states of oxidation in which iron is

[1] Received September 1, 1921. Read at the Joint Meeting of the Glass Division of the American Ceramic Society and the English Society of Glass Technology in Pittsburgh, September 2, 1920.

found in the glass and the difference in absorption produced by each state, ferric iron generally giving a yellowish tint and ferrous iron producing green. The effect on transmission of the same approximate total iron content varies in the different types of glass; the transmission of borosilicates being in general higher than that of flints, ordinary crowns or barium crowns. The statement that soda increases color when substituted for potash in glass is frequently made, although detailed determinations of iron contents of materials and of final glasses are usually lacking when this statement appears.

In order to obtain specific information concerning the effect of iron when present in the batch in different forms, an extensive series of melts on experimental glasses was made[1] by our colleagues, F. E. Wright and N. L. Bowen, who introduced iron into glass batches as metallic iron, magnetite, ferrous carbonate, and ferric oxide. The ferrous and ferric iron in these glasses was subsequently determined[2] and transmissions measured. The relation between ferrous and ferric iron in any particular series of glasses did not appear in general to be dependent upon the form in which the iron was introduced into the batch, and this condition indicated immediately that some equilibrium was approximately established between these two states of oxidation. The melts were made in small open pots (12 $\times$ 12 inches) in a recuperative furnace which was fired with artificial gas, and the first conclusion regarding the state of oxidation of the iron in the glass was naturally that the ratio between ferrous and ferric iron was that developed by the action of the products of combustion.

In the present paper there is expressed another point of view which is not intended to supplant the idea that the ratio of ferrous to ferric iron in a glass is dependent upon the composition of the products of combustion above the melt, but rather to supplement this conclusion by showing that ferric oxide dissolved in glass can be "reduced" to the ferrous state when heated in pure air, that is, under "oxidizing" conditions.

[1] At the Bausch and Lomb Optical Company.

[2] Some of these analyses have been published by Ferguson and Hostetter. This Journal, 2, 608-621 (1919).

Dissociation of Ferric Oxide

When ferric oxide is heated *in vacuo* it gives off oxygen. The relations between oxygen pressure, temperature and composition have been investigated.[1] As oxygen is evolved an equivalent amount of "ferrous oxide" is formed which in all probability dissolves in the ferric oxide to form a solid solution. This conclusion is based upon microscopical evidence and also on the characteristics of the isotherms for this system. Figure 1 shows the characteristic shape of the isotherms actually secured and also, in the dotted lines, the probable shape of the isotherms at other temperatures. It has also been determined that ferric oxide, even when heated in air, loses some of its oxygen and forms a corresponding amount of ferrous oxide. A slight oxygen loss takes place as low as 1000°C and this loss increases at higher temperatures until melting takes place at 1590°C, when the product consists of magnetite which contains 31.1 per cent FeO. Oxygen lost at high temperatures is reabsorbed at lower temperatures if the charge is cooled slowly—thus indicating that the action is reversible.

The formation of "ferrous oxide" under these conditions—by dissociation—is to be carefully distinguished from the reduction of ferric oxide by such constituents of furnace gases as carbon monoxide and hydrocarbons. These gases not only dilute the oxygen, thereby lowering its partial pressure, but they remove oxygen from the already reduced ferric oxide and combine with it chemically, thus increasing the amount of "ferrous oxide." The formation of ferrous oxide by dissociation in the first case takes place under what are ordinarily considered to be oxidizing conditions. In fact, it has been shown that ferric oxide loses weight with attendant formation of ferrous oxide in one atmosphere of oxygen at 1300°.[2]

The order of magnitude of the amount of ferrous oxide formed when ferric oxide is heated to different temperatures in air is shown in table 1. The data presented here as series 1 have been recalculated from those given in the paper last quoted. The data of series 2 represent ignition experiments under differ-

[1] Sosman and Hostetter, *J. Am. Chem. Soc.*, 38, 807–833 (1916).

[2] Hostetter and Sosman, *Ibid.*, 38, 1188–1198 (1916).

Table I.—System Fe_2O_3–Fe_3O_4

Ferrous oxide in equilibrium at different temperatures with the oxygen pressure in air (152 mm.).

The first three values under "Per cent FeO" resulted from series 1, the other six from series 2.

Temperature °C	1150	1200	1250	1283	1350	1377	1401	1450	1590
Per cent FeO	0.053	0.067	0.082	0.4	0.8	1.85	14.1	19.9	31.1

ent conditions. The data of series 1 were obtained by following changes in weight that occurred when ferric oxide was heated alternately in air and oxygen at certain temperatures under controlled conditions that ensured freedom from reducing material of any description. The charges were held in "alundum" boats placed in a porcelain tube heated electrically and the air and oxygen used were specially purified. In series 2 the charges were held in a platinum crucible heated in an electric furnace for 1½ hours at the given temperature, while a slow stream of air was passed over the charge. The thermocouple in this series was inserted in the charge. Since platinum reduces the oxide of iron in contact with it at high temperatures,[1] suitable precautions were taken to ensure the removal of the layers in contact with the crucible before analyses were made to determine the amount of ferrous oxide formed; weight changes were not followed here.

The data of series 1 and 2 are plotted in figure 2. Such a curve represents the isobar for the system Fe_2O_3–Fe_3O_4–O_2 at 152 mm. oxygen pressure which is marked by the heavy horizontal line in figure 1. The general shape of the curve of figure 2 is in satisfactory agreement with that indicated by the points on the 152 mm. isobar if the isotherms for higher temperatures follow the same curvature as those for 1100° and 1200°.

Dissociation of Ferric Oxide in Clays

Certain qualitative results obtained by Kinnison[2] may be mentioned here. As far as we know, they are the only results recorded which have been obtained under oxidizing conditions. He subjected four different clay mixtures containing 5 per cent

[1] Sosman and Hostetter, *J. Wash. Acad. Sci.*, **5**, 293–303 (1915).

[2] *Trans. Am. Ceram. Soc.*, **16**, 136 (1914).

Fe_2O_3 to high temperatures under oxidizing conditions (air) and noted the colors of the slabs after exposure to a definite temperature for 1.5 hours. At 1100° all of the ignited specimens were red. At 1250° one of the tests yielded a greenish brown glass, while the other three varied from cream color to pink.

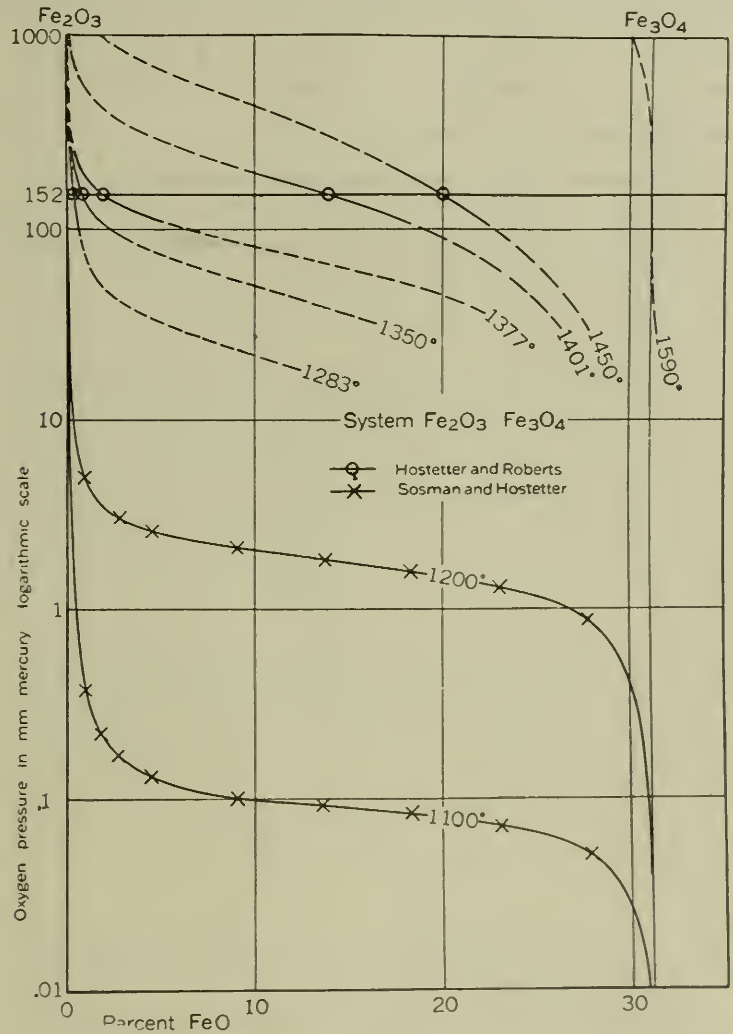


FIG. 1.—*Iron oxides alone.* Dissociation pressure and composition (isotherms).

At 1400°, the maximum temperature, another mixture yielded a black glass and the other two were black in color but not vitrified. As the temperature was increased from 1100° it was evident that reduction of the ferric iron causing the initial red color had taken place and that the ferrous iron so formed was responsi-

ble for the darkening in color. Kinnison attributed the formation of ferrous oxide to a "transition" of the higher to the lower oxide, but, as shown above, ferric oxide dissociates over a considerable range in temperature with the formation of a solid solution instead of yielding a second phase. The black specimens obtained by Kinnison were clay bodies mixed with solid solutions of ferrous oxide in ferric oxide with possibly local zones of fusion around each particle of iron oxide. He points out that ferrous iron yields a more fluid glass than ferric iron.

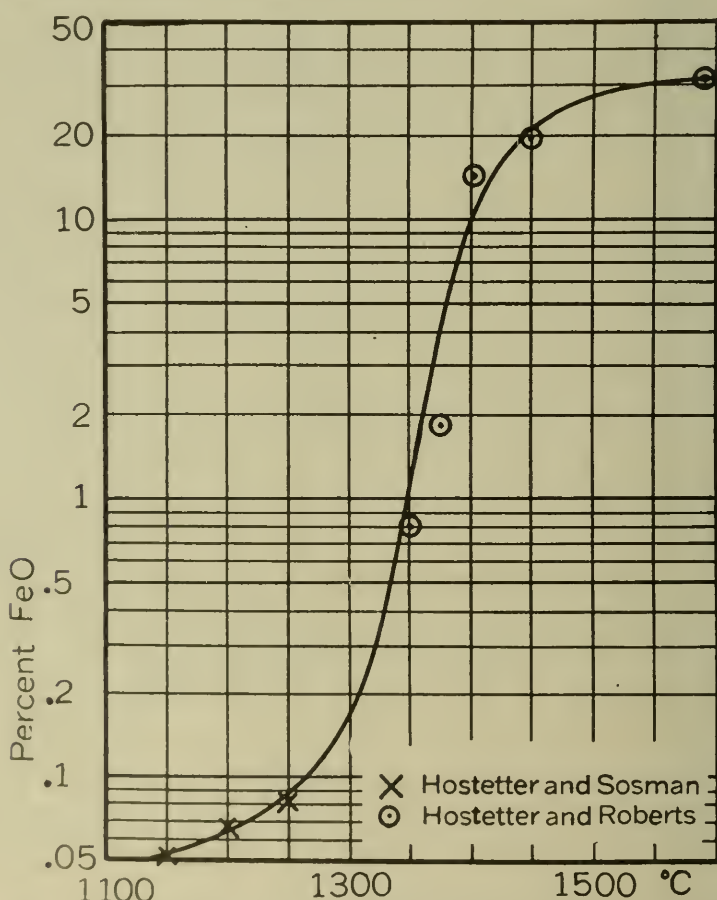


FIG. 2.—*Iron oxides alone.* Composition and temperature for charges heated in air (152 mm. isobar).

Dissociation of Ferric Oxide Dissolved in Glass

It can also be readily enough shown that ferric oxide dissolved in glass loses oxygen at higher temperatures, even under

the oxygen pressure of the air. This is evidenced not only by the change in color of the glass from yellow to green, as the glass is fined at successively higher temperatures, but also by actual chemical analysis of the glass. In the experimental work which follows it will be shown that ferric oxide dissolved in a glass at a comparatively low temperature loses oxygen when the glass is subsequently heated to a higher temperature in pure air. Some of the experiments that will be described below were carried out in collaboration with R. B. Sosman about 1913 in preliminary work on the system diopside: ferrous silicate. The other experiments were made more recently in order to demonstrate the applicability of these results to actual glass-making processes.

The actual dissociation in any particular case will depend on the composition of the glass in which the ferric oxide is dissolved. Any variation in composition of the glass will be reflected in the dissociation pressure at a given temperature since a change either in the number or character of the components, or the concentration in a given system, will necessarily raise or lower the pressure in a manner depending on the characteristics of the system.

The method of experimentation was, briefly, to make up a glass containing ferric oxide at a low temperature. Subsequently a portion of this glass was heated to a definite higher temperature in a stream of air for a fixed length of time. The crucible containing the glass was then removed from the furnace and the melt quenched in water. The color of the glass was noted and then the total iron and ferrous iron contents were determined.

In the first series, the glass used consisted of diopside ($CaSiO_3.$-$MgSiO_3$) to which was added 8 per cent of iron as ferric oxide, and the equivalent amount of silica to make ferrous silicate, $FeSiO_3$. The results obtained with this glass are presented in table 2. We may note here that the glass fined at about 1400° contains approximately 20 per cent of the total iron in the ferrous condition; the color of this glass is decidedly brown. At 1589°, however, no less than 41 per cent of the total iron is ferrous and the color is green. Between these two extremes the color varies from brown through olive green to clear green. The relation between percentage of ferrous oxide and temperature is shown in figure 3.

TABLE 2

Change in state of oxidation of iron oxide dissolved in diopside ($CaSiO_3$.-$MgSiO_3$) glass on heating to different temperatures in air.

Initial total iron content of glass, 8.08 per cent.

Minutes at maximum temperature	Maximum temperature, °C	Ferrous iron % of total iron	Color of glass
—	1397	20.4	brown
16	1407	21.6	——
—	1422	18.5	——
70	1431	26.0	olive
20	1526	25.9	——
—	1526	39.4	——
20	1530	29.3	——
—	1530	30.7	——
15	1589	41.2	bright green

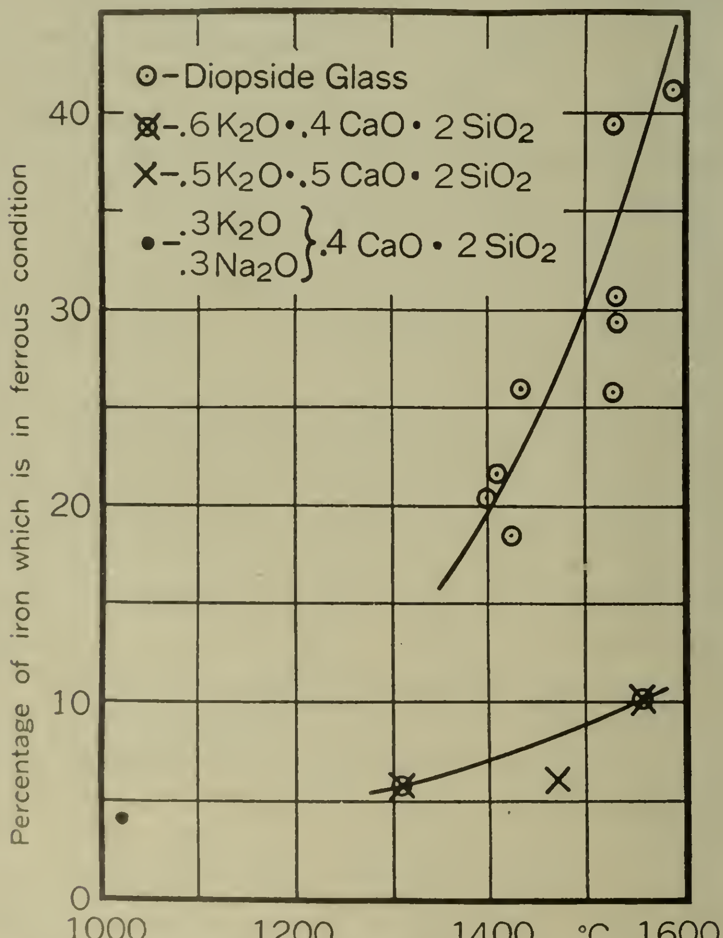


FIG. 3.—*Iron oxide dissolved in glass.* Composition and temperature for charges heated in air (152 mm. isobar).

A series of crown glasses was made up and similar tests made at different temperatures. The compositions and results obtained are given in table 3. It will be noticed here that the percentage of ferrous iron formed at a given temperature is

TABLE 3

Ferrous iron in glasses fined at various temperatures.
Initial total iron content of glass, 0.7 per cent.

No. of glass	Composition		Time at high temperature hrs.	Maximum temperature °C	Ferrous iron % of total iron	Comparative color of glass
R478	$0.3K_2O$ $.3Na_2O$ $.4CaO$	$2SiO_2$	48	1020	4.1	lemon yellow
6377A	$0.6K_2O$ $.4CaO$	$2SiO_2$	5	1310	5.8	greenish yellow
6368A	$.5K_2O$ $.5CaO$	$2SiO_2$	1	1470	6.0	yellowish green
6372A	$.6K_2O$ $0.4CaO$	$2SiO_2$	½	1555	10.1	bright green

of an entirely different magnitude from that obtained with the diopside glasses. The amount of oxygen lost at a given temperature depends upon the composition of the glass and will change with each variation in composition. It may be noted here that when these glasses were fined at 950° to 1000°, the color was lemon yellow. After being held for 13 minutes at 1555° the color was bright green, even though only 10 per cent of the total iron was in the ferrous condition.

Discussion of Experimental Results

From the results presented it is apparent that the formation of ferrous oxide in a glass may result from dissociation of the higher oxide as well as from possible reduction by gases. The two causes may operate in a given case, one or the other predominating, depending on conditions. However, since, in the case of dissociation, oxygen is reabsorbed as the melt cools, it is obvious that, in the later stages of stirring optical glass when the fire is off, there are obtained excellent conditions for the attainment of equilibrium with the oxygen of the air. Cooling a glass melt in air without stirring presents less opportunity

for the absorption of oxygen, but the case is quite different with the usual practice for optical glass. It is appropriate to note here that the amount of ferrous iron found in the experimental optical glass melts mentioned earlier in this paper ranged from 7 to 38 per cent of the total iron—the same range of values covered by the experiments presented in this paper.

It is well known that certain types of optical glass generally possess a higher transmission than other types. Aside from the facts that the denser glasses give a more intense color with a given impurity than glasses of less density (and lower index of refraction) and that the different alkalies give different colors with the same impurity, it is also common experience that borosilicates, for instance, usually possess higher transmission than barium crowns. A pot of the latter glass at the Bausch and Lomb Optical Company, pronounced "poor color" when examined by Mr. V. Martin, the experienced glass-maker in charge, was later found to contain iron equivalent to 0.075 per cent Fe_2O_3. However, a pot of borosilicate, of "good" color (absorption of light 1.57 per cent per cm.) was later found to contain 0.080 per cent total iron as Fe_2O_3. In the first case the glass was noticeably green with a bluish tinge; in the latter glass the color was not nearly so green.

Such results may be an indication that there is considerably less dissociation in the case of boron glasses than in barium glasses. Similarly there may well be large differences in the effect on the dissociation of ferric oxide dissolved in glasses containing sodium on one hand and potassium on the other, thus accounting in part for the better color of potash glasses and the fact that when manganese dioxide is used as a decolorizer less of it is necessary with potash than with soda glasses. If this decolorizer acts primarily as an oxidizing agent the smaller quantity required with potash glass would indicate less dissociation than with soda glasses.[1]

[1] Potash glass made from raw materials containing the same amount of iron as the corresponding soda glass might still show less iron than the soda glass because the higher fluidity of the latter glass at high temperatures would presumably cause more pot corrosion and correspondingly greater iron absorption.

Since the amount of dissociation increases with temperature it is obvious that the higher the temperature at which an iron bearing glass is fined the greener the color. And also it follows that more decolorizer is required for a glass fined at the elevated temperature than at a lower temperature. Of course, other factors such as pot attack and volatilization (or dissociation) of decolorizer are also increased as the temperature is raised, but added to these is the fact demonstrated in this paper that dissociation of the iron oxide increases with increasing temperature of the glass.

Incidentally, it may be noted here that the foregoing data furnish the basis for an additional explanation of the phenomenon noted by Washburn[1] that the color of optical glass increases after stirring is started. His theory was, briefly, that iron or iron oxide volatilized or carried mechanically from the burners of the furnace, was absorbed by the glass[2] from the furnace atmosphere during the stirring process. The demonstration of the present paper indicates another factor that plays a part in the intensification of color observed by Washburn, namely, dissociation of the iron oxide already present in the glass.

While dissociation of the iron oxide present in the glass would account for some intensification of color after stirring was started, there is another important factor giving the same effect,—the mixing, by the motion of the stirrer, of the more basic layer on the bottom of the pot with the other portions of the glass. One observation made at the plant of the Bausch and Lomb Optical Company may be cited here in support of this explanation. A proof taken from a melt of dense flint (n_D 1.65) before the glass was fine gave an iron content of 0.019 per cent Fe_2O_3. This sample was very light in color and from its index of refraction F. E. Wright estimated it to contain 46 per cent PbO. The final glass, however, showed a very much deeper color and from its index of refraction it was estimated to contain 51 per cent

[1] This Journal, 1, 637 (1918).

[2] Iron salts in general are not very volatile. In previous work at the Geophysical Laboratory in which ferric oxide was heated to higher temperatures than those found in glass furnaces no evidence of volatilization of ferric oxide was noted.

PbO and analysis showed no less than 0.062 per cent Fe_2O_3. From these observations it is quite obvious that the lead oxide had segregated during melting and had formed a lead-rich layer on the bottom of the pot. This layer was very corrosive and had attacked the pot, dissolving therefrom a certain amount of iron. Consequently when this heavy layer was stirred up through the rest of the glass the color was increased not by absorption of iron from the furnace gases, but simply by mixing the iron-carrying lower layer with the bulk of the glass.

Geophysical Laboratory
Carnegie Institution of Washington

CERAMIC ABSTRACTS

Author Index[1] to Abstracts for November

[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. **The manufacture of ultramarine blue.** M. Sauvageot. *Rev. prod. chim.*, **24**, 141–8, 205–12(1921).—General description of the raw materials employed and of the method of manuf. of ultramarine blue, together with tables giving 22 analyses of blues and 3 analyses of ultramarine green and a brief mention of some of the modern theories on the constitution of ultramarine and of the improvements which should be effected in the mfg. process. A. P. C. (*C. A.*)

2. **The industrial preparation and filtration of colloidal solutions and masses.** J. H. Frydlender. *Rev. prod. chim.*, **24**, 173–82(1921).—The main principles of colloidal chemistry are very briefly reviewed. Plauson and Block's "colloidogenetic" mill is described together with its application to various industries including fuller's earth, fuel (liquid coal), graphic lubricants, and ultramarine. Plauson's method of ultrafiltration (see Schmitt, *C. A.*, **14**, 3763) is described and mention is made of its applications in the industries of *ceramics*, mineral pigments, and dust prevention. A. P. C. (*C. A.*)

3. **The measurement of color.** C. E. K. Mees. Eastman Kodak Co. *J. Ind. Eng. Chem.*, **13**, 729–31(1921).—Methods of color measurement are discussed and the spectroscope, spectrometer, colorimeter, monochromatic analyser, trichromatic analyser, and the Eastman colorimeter described. The last is robust in construction and uses three colored wedges, each wedge absorbing $^1/_3$ of the spectrum. With these wedges and a fourth grey wedge any color can be perfectly matched and quantitatively measured. The instrument is especially useful for the rapid and quantitative measurement of the color of *glasses*, *porcelains*, and *enameled* surfaces. Ed.

4. **Clays and earths. In the tariff act of 1913.** U. S. Tariff Commission. *Tariff Information Surveys*, **1921.** 5c a copy from Supt. of Documents, Wash. D. C.—Kaolin or China clay: summary: *General Information* on tariff classification, descrip., uses, domestic production, geographical distribution, ball clay, equipment, methods of manuf., organization, domestic production and consumption, domestic exports, foreign production, imports and revenue, costs and prices, tariff history, competitive conditions, tariff considerations; *Production in the U. S.*, states, (kaolin and paper clay) and principal countries; imports by countries, imports for consumption, prices, rates of duty, court and treasury decisions.

Clays other than kaolin or China clay: summary; ball clay; common blue clay and all other clays; general information on tariff classification, description and uses, domestic production, foreign production, imports, prices, tariff history, competitive conditions, tariff considerations; domestic production of ball clay; imports by countries; imports for consumption, domestic exports; prices; rates of duty; court and treasury decisions.

Fuller's earth: summary; general information on tariff classification, description, uses, domestic production, foreign production, imports, prices, tariff history, competitive conditions; domestic production; imports for consumption; prices; rates of duty.

Fluorspar: summary of description, domestic production, foreign production, competitive conditions, imports, prices, tariff history, duties in foreign countries, tariff questions involved; general information on description, grades, fluorspar for optical purposes, uses, occurrence, deposits in the U. S., foreign deposits, preparation, production, imports, markets and prices, consumption; production in the U. S., states; production in principal foreign countries; imports by countries; imports for consumption, calendar years; imports for consumption, fiscal years; prices, rates of duty; competitive conditions; court and treasury decisions.

Feldspar, crude and manufactured: general information on tariff classification, description, uses, domestic production, foreign production, imports, prices, tariff history, competitive conditions; production in the U. S.; production in foreign countries; rates of duty; court and treasury decisions. Ed.

5. **New Ceramic School in Canada.** ANON. *Chem. Met. Eng.*, **25**, 209 (1921).—A ceramic department is to be established in the University of Saskatchewan, Saskatoon, Can. W. G. Worcester, a graduate of the Ohio State University Ceramic Department, has been appointed professor in the new department. H. F. S.

6. **Molecular force and plasticity of clays.** HERBERT CHATLEY. *Trans. Ceram. Soc.* (Eng.), **19**, 1–2(1919–20).—Suggestion is made that plasticity (and also, when the molecules of the fluid are considered, the specific "colloid" properties of sub-divided matter) is due to the presence of molecular forces comparable with weight or other external agency. H. F. S.

PATENTS

7. **Silicate containing materials of fat-like character and high absorptive power.** ROBERT MARCUS. Ger. 322,088, Aug. 22, 1917. Sol. silicates are made to interact with hydroxy acids in suitable ratios. As hydroxy acids, lactic acid, glycolic acid or the like may be employed. The resulting salts remain emulsified in the state of finest subdivision with the colloidal silicic acid. They prevent the conversion of the silicic acid to crystalline form and are the cause of the cleansing power of the mass. The mass is used as a *substitute for soap*. It is claimed to be serviceable also as *lubricant*. (*C. A.*)

BOOK

8. Sprechsaal-Kalender für die Keramischen, Glas-ünd verwandten Industrien. 1921. Edited by J. KOERNER. Coburg: Müller & Schmidt. M 7.50. For review see *Tonind.-Ztg.*, **45**, 464 (1921). (*C. A.*)

Apparatus and Instruments

9. **Suggestions for calibrating base metal thermocouples by the freezing point method.** KIRTLAND MARSH. *Chem. Met. Eng.*, **24**, 1071(1921).—Iron protection tubes can be used in molten metallic tin and aluminum without contaminating the metals, if the tubes are heated to 900°F and then dipped into a wash of one part plumbago and two parts water. For use in molten copper a second dipping is given into a wash of one part lime and one part water. H. F. S.

10. **Electrical pyrometry.** ANON. *Elektrochem. Z.*, **27**, 46, 52, 63, 72, 81, 85(1920–21). C. G. F. (*C. A.*)

11. **Drying theory; most economical temperatures; graphic determination of moist air.** E. HOEN. *Z. Ver. deut. Ing.*, **63**, 821–6(1919); *Mech. Eng.*, **42**, 169–71(1920); *Science Abstracts*, **23B**, 561–2.—A discussion of the most economical temp. and most economical degree of satn. for the air at the outlet from the drying chambers; discussion of influence of air pressure; and graphical methods for the solution of problems in connection with processes of drying. The conditions most easily attainable mechanically and still satisfactory from an economic point of view lie, so far as temp. is concerned, between 60 and 80 and 60 to 80% of satn. In this case we expend roughly 1 kg.-cal. of heat to take care of 1.4 g. of water, which means an expenditure of 0.7 kg.-cal. of heat for 1 g. of water, or 700 kg.-cals. of heat for 1 kg. of water. This is very nearly the same as the heat necessary to evap. 1 kg. of water at atm. pressure, which is 640 kg.-cals. Under this condition the efficiency of drying is close to 90%. H. G. (*C. A.*)

BOOKS

12. BÜHLER, F. A.: **Filtern und Pressen, zum Trennen von Flüssigkeiten und festen Stoffen.** 2nd Ed. revised by Ernest Jänecke. Leipzig: Otto Spamer. 172 pp. M 37. For review see *Chem. Weekblad*, **18**, 224 (1921). (*C. A.*)

Chemistry, Physics, and Geology of Raw Materials

13. **The colorimetric determination of iron in silicates with ammonium thiocyanate.** JOSEF MATEJKA. *Chem. Listy*, **15**, 8–13(1921).—Thomson (*J. Chem. Soc.*, **47**, 493(1895)) and Proskauer made use of NH_4CNS for the colorimetric detn. of Fe. The procedure adopted by M. is as follows: Into a 20-cc. colorimetric tube place 1–2 cc. of standard Fe soln. (a soln. of $NH_4Fe(SO_4)_2.12H_2O$ in 0.5% H_2SO_4 giving a concn. of 0.01 g. of Fe_2O_3 per l.), 8 cc. of a mixt. consisting of 1 part of 10% HNO_3 and 3 parts of 10% citric acid by vol., and then add 8 cc. of a 10% soln. of NH_4CNS. Dil. the mixt. to the 20 cc. mark. To two other tubes add the same solns. with the exception of the one containing the Fe and dil. to a vol. of about 19 cc. To one of these add drop by drop until the intensity of coloration is the same as in the standard tube, the soln. of the sample to be tested obtained by dissolving its pyrosulfate fusion in 0.5% H_2SO_4 and dilg. to 250 cc. Then make a second detn., taking care to have the final vol. in the colorimetric tube exactly 20 cc. The following precautions are to be observed: The thiocyanate must be added in excess and its concn. must be the same in both tubes (cf. Tatlock, *Z. anal. Chem.*, **28**, 706(1889)). K_2SO_4 and $KHSO_4$ cause a reduction of the intensity and change the color from pink to orange. NaCl, $MgCl_2$, $CaCl_2$, $TiCl_3$ and Al salts have a detrimental effect. The interference of all these salts is inappreciable if the soln. to be tested is sufficiently acidified with HNO_3 and citric acid before the addition of thiocyanate. The concn. of the Fe in the

soln. in the tube should be between 0.00001 and 0.00002 g. Fe_2O_3. The reagents should be absolutely free from Fe. M. has found the above methods as satisfactory as the ether method of Lunge (*Z. angew. Chem.*, 1886, 3).

JOHN M. KRNO (*C. A.*)

14. The composition of dolomites. IRENE EVERMAN, O'NEAL MASON, AND GLENN BROWNING. *Chem. News*, **122**, 109–10(1921).—Thirteen analyses of dolomites from the following localities are given: Le Grand, Iowa; Gouverneur, N. Y.; Cape Breton Island; Frizington, England; Marquette, Mich.; Tuckahoe, N. Y.; New Almaden, Calif.; Providence, R. I.; White Pine, Nev.; Guanajuato, Mex.; Nagyag, Transylvania; Clayton, Iowa; and Dubuque, Iowa. S. G. GORDON (*C. A.*)

PATENT

15. Alumina from clay. WILHELM DAN BERGMAN. Norw. 30,846, June 28, 1920. Clay is decomposed with an acid soln. and the $Al(OH_3)$ pptd. by means of an alk. soln. for which purpose the solns. forming in the electrolysis of a neutral sulfate soln. are used. From the acid anode liquid the neutral sulfate is sepd. by crystn., said liquid then being used to decompose the clay. The resultant Al soln. is sepd. from the insol. constituent (silicic acid) and pptd. with the alk. cathode liquid. $Al(OH)_3$ then seps. off and neutral sulfate re-forms, which is again returned to the process.

(*C. A.*)

Refractories and Furnaces

16. Judging sands for foundry use. HENRY B. HANLEY AND HERBERT R. SIMONDS. *Foundry*, **48**, 772–4, 867–8, 875, 921–2(1921).—Sand for foundry use has 3 characteristics: refractoriness, cohesion and porosity. Foundry sands may be divided into molding sand, core sand, facing sand, fire sand, gravel, high-silica sand and parting sand. Molding sand is usually a natural sand and a mixt. of quartz, feldspar and clay. Core sand is an artificial sand containing a binder as molasses. Chem. analyses of typical sands are given and their interpretation is discussed. Other tests for sand are also discussed. The best test for the amount of bond in a sand is the adsorption of methyl violet. This is best detd. by adding the dye to a soln. of the colloids from the sand till a color is produced and then removing the dye by means of mordanted cotton yarn and comparing the color of the yarn with that of standards. The strength of the bond depends on the surface of the sand particles as well as on the amt. of bond. Methods of chem. and mechanical analysis are given in detail. R. S. DEAN (*C. A.*)

17. New German refractory product. ANON. *Chem. Met. Eng.*, **24**, 1070(1921).—A coating composed of 75% carborundum and 25% sodium silicate is painted on to fire bricks. The layer is about one fiftieth of an inch thick and fuses to a glassy veneer which is said to be remarkably resistant to mechanical injury and the chem. action of flames. It has been used successfully as a lining for gas retorts. H. F. S.

18. **Refractories for bottom-connected electric furnaces.** F. W. BROOKE. *Iron Age*, **106**, 1316(1920).—Successful operation of elec. furnaces having a conductive bottom depends upon: correct application of the current, the use of good double-burned *dolomite* and a good pitch or tar, and good operators. The transformer connected directly to the bottom is designed to carry a heavier current than that carried by each electrode, which necessitates the bottom transformer having such a kw.-amp. capacity and a secondary voltage that when the top electrodes carry equal currents there is a perfect balance on the primary side. These features insure carriage of all current given to the furnace, no elec. trouble from the deep holes formed during melting, and long life of furnace linings. A good pitch consists of the residue from coal tar distn. up to 250°. Quick "coming on" of the conductivity is effected by designing the furnace and putting in the bottom in such a way that all the excess tar will quickly drain away. W. H. BOYNTON (*C. A.*)

19. **Quartzites and silica bricks.** F. WERNICKE. *Stahl u. Eisen*, **40**, 432–7(1920).—For the manuf. of silica bricks in Germany, rocks of 3 different geological formations are employed, *viz.*, felsquartzites—marine deposits belonging to the Devonian period—which have a dense structure of closely interlocked crystals, the individual quartz grains being relatively large, with sharply defined edges and a characteristic wavy extinction of color. Carboniferous sandstones, consisting of medium-sized quartz crystals, some having sharply defined edges and closely interlocked, while in others the edges are corroded and the crystals are sepd. by a small quantity of cement-like material; and glacial or "amorphous" quartzites—fresh water deposits of Tertiary origin belonging to the period of lignite formation—consisting of very small grains of quartz with rounded edges distributed uniformly through an amorphous ground-mass of siliceous gel or "basaltic" cement. All these quartzites are very rich in silica; their refractoriness corresponds to that of cone 36 (1790°). In the manuf. of silica bricks it is not necessary to effect a complete conversion of quartz into tridymite provided the max. expansion is attained. With glacial quartzites this is reached by one firing at 1450° without excessively prolonged heating but silica rocks from the coal measures require 2 or 3 firings before they attain their max. expansion, and felsquarzites continue to expand after several prolonged firings. By examn. under the microscope with a magnification of only 45 diams. using polarized light, useful quartzites can be distinguished from the useless ones, as the former contain minute crystals in a glassy ground-mass, while the latter consist almost wholly of larger crystals or sharply defined fragments of such crystals. For the arches of elec. and other metallurgical furnaces, silica bricks should be made of glacial or Tertiary quartzites. For glass-melting furnaces, where the temp. is not so high, silica bricks made from coal measure quartzites are satisfactory, and may be recommended on account of their greater purity and the lesser risk of spoiling the glass. Coal measure quartzites may also be used for silica bricks employed in regenerators, coke ovens, etc. Mixts. of Tertiary and coal measure quartzites are also used. Coarse cryst. quartzites are only suitable for low-grade silica bricks used in annealing furnaces, and so forth. (*C. A.*)

20. Laboratory furnace for deformation tests of refractories. L. R. OFFICE. *Chem. Met. Eng.*, **25**, 162(1921).—The furnace consists of an ordinary pot furnace with one burner, set tangentially to the inner surface. Natural gas and compressed air at 30 pounds pressure are used. For high temp. the air is preheated by being passed through a heater consisting of four two-foot lengths of two inch iron pipe connected at the ends with U's and spaced so that the flame from two gas burners will surround them. The air is raised to a temp. of 250°C at the burner and cone 35 can be reached in the furnace in 35 min. H. F. S.

PATENTS

21. Refractory articles. O. REBUFFAT. Brit. 159,865, Jan. 5, 1921. Bricks and other refractory articles composed chiefly of SiO_2 are made from a mixt. contg. a small proportion, *e. g.*, 0.45% of phosphoric, tungstic, molybdic, boric or other acid stable at high temps., or a salt of such acid. The bricks are baked at a temp. of 1,300–1,500° to convert the SiO_2 into modifications of low sp. gr., such as tridymite. (*C. A.*)

22. Refractory substances. OSMOSIS CO., LTD., D. NORTHALL-LAURIE AND W. R. ORMANDY. Brit. 159,537, Jan. 22, 1920. Refractory articles are made by firing specially purified china clay without a flux at temps. below 1500°. The clay is purified by the methods set forth in 2379, **1911** (*C. A.*, **6**, 1964), 3364, **1911**(*C. A.*, **6**, 2036), 27,930, **1911** (*C. A.*, **7**, 1846), 27,931, **1911** (*C. A.*, **7**, 1846), 28,185, **1911** (*C. A.*, **7**, 1846), and 14,235, **1912** (*C. A.*, **7**, 4055), *e. g.*, it is made into a slip with a dil. electrolyte such as NaOH or Na_2SiO_3, allowed to stand for about 24 hrs., and is either subjected to electroösmosis, or pptd. by a coagulating agent such as $Al_2(SO_4)_3$ and reconverted to the sol. condition by a treatment with an alkali. The purified clay is made unto a slip to which a grog made of vitrified china clay may be added to minimize contraction on firing. (*C. A.*)

BOOK

23. Special Reports on the Mineral Resources of Great Britain. XIV. Refractory Materials: Fireclays. Memoirs of the Geological Survey. London: H. M. Stationery Office. 243 pp. 8s. (*C. A.*)

Abrasives

24. Abrasive materials. In the tariff act of 1913. U. S. TARIFF COMMISSION. *Tariff Information Surveys*, **1921.** 5c a copy from the Supt. of Documents, Wash., D. C.—This bulletin deals with the description of abrasive materials, their method of manuf., list of mfgrs., production, consumption, and imports. The statistics regarding domestic production are classified by states and by kinds; those regarding imports, by countries and by kinds. Prices, rates of duty, and court and treasury decisions on tariff classifications and rates are also covered. Ed.

White Ware and Porcelains

See Abst. Nos. 3 and 4.

Glass

25. **Quartz glass and the mercury lamp.** G. BERLEMONT. *Bull. soc. encour. ind. nat.*, **133**, 254–60(1921); 2 figs.—During the war B. was induced to resume his attempts to perfect the manuf. of the mercury vapor lamp. In collaboration with Henri George and others he succeeded in making a lamp for medical and experimental uses. Tungsten was employed for sealing with the quartz glass and the arc was not formed in a vacuum but at atmospheric pressure, thereby attaining two improvements: making the lamp more robust and simplifying the lighting procedure. J. B. PATCH (*C. A.*)

26. **Canadian glass industry in 1918.** ANON. *Chem. Met. Eng.*, **25**, 115(1921).—Nine glass factories were in operation. Six made lamp chimneys, lantern globes, bottles and other pressed and blown ware; two made vials and chemical glassware; one made sheet glass. The total production amounted to $6,578,000. Of this $35,000 was exported. During the same year $5,480,000 worth of glassware was imported. H. F. S.

27. **Electrically heated glass-annealing lehrs.** E. F. COLLINS. *Chem. Met. Eng.*, **25**, 119.—See THIS JOURNAL, **4**, 600(1921). H. F. S.

PATENT

28. **Light filters.** E. L. FRIEDMANN & Co. Brit. 159,179, Feb. 4, 1921. Filters for lamp-shades, etc., for producing artificial daylight by gas-filled metallic filament lamps consist of glass in which cobalt-blue and nickel-green colors are melted together in one charge. Other additions such as $CuSO_4$ may be used for the production of a green color. (*C. A.*)

Enamels

29. **Electric vitreous enameling furnace.** ANON. *Chem. Met. Eng.*, **25**, 206. See THIS JOURNAL, **4**, June (1921). H. F. S.

30. **Electric heat raises enameling output.** J. W. CARPENTER. *Elec. World*, **77**, 873–5(1921).—See THIS JOURNAL, **4** (1921). W. H. BOYNTON (*C. A.*)

See also Abst. No. 3.

Cement, Lime and Plaster

31. Lime, gypsum, and cements. **In the tariff act of 1913.** U. S. TARIFF COMMISSION. *Tariff Information Surveys,* **1921.** 5c a copy from Supt. of Documents, Wash., D. C.—Lime: summary; *General information* on description, important uses, domestic production (raw materials, process of manuf., organization, geographical distribution, domestic productions, exports), imports, tariff history, competitive conditions (general situation, competition in Wash. district, Canad. duty on lime); *Production in the U. S.*, by states, by uses, total lime burned and sold and hydrated lime (since 1906, quantity,

value, average price, number of plants); imports by countries; imports by consumption, since 1907; domestic exports, since 1909; rates of duty, court and treasury decisions.

Gypsum, crude, and calcined, and manufacture of: summary; general information on tariff classification, description and uses, domestic production (raw material, equipment, methods of manuf., organization, geographical distribution, history of the industry, domestic production and consumption, domestic exports); foreign production; imports; prices; tariff history; competitive conditions; tariff considerations; production in the U. S. of gypsum, and manuf. of; production in principal countries; imports by countries of plaster rock or gypsum (crude, ground or calcined, crude and ground or calcined, manuf. of), cement, Keene's cement; imports for consumption of plaster rock or gypsum, crude, ground or calcined; imports for consumption of cement, Keene's cement and other plaster rock or gypsum, plaster of Paris, and so forth; domestic exports, prices, rates of duty, court and treasury decisions.

Cement, Roman, Portland, and Other Hydraulic: summary; general information on tariff classification, description, uses, military importance, domestic production of raw materials, equipment, mfg., methods, organization, geographical distribution, history of the industry, domestic production, and consumption, domestic exports, foreign production, imports, prices, tariff history, competitive conditions, tariff considerations; production in the U. S., imports by countries; imports by consumption; domestic exports; average factory price per barrel; rates of duty; court and treasury decisions.
ED.

32. Specifications for the color of gypsum plasters. W. E. EMLEY AND C. H. FAXON. *Chem. Met. Eng.*, **24**, 1054–5(1921).—Advocates the use of spectrophotometric examination and grading. H. F. S.

33. Ferroportland pozzuolana mixtures. FABIO FERRARI. *Giorn. chim. ind. applicata*, **2**, 549–54(1920).—F. comes to the following conclusions from expts.: (1) Normal agglomerates made up of portland-pozzuolana mixts. show, in general, an imcomparably greater resistance to the action of sulfates and chlorides than pure portland agglomerates, owing to the lower sp. permeability of the 1st type and its lower content in Ca aluminates. They become, therefore, passive after a longer or shorter period of time to the disintegration to which all mortars are subjected that contain strongly basic aluminates, as to alterations in their superficial continuity (the essential coeff. of mechanical resistance of every cementitious mass constituted of hydrated Ca silicates). (2) Normal agglomerates constituted of ferroportland (or portland free of binary Fe and Al compds.), in that they are free from defects derived from the presence of aluminates, undergo during long periods of time a regression because of the diffusion of CaO due to their high sp. permeability and the instability of their protective crust, characters with which they are endowed because of the high basicity of ferroportland. (3) Mortars constituted of ferroportland-pozzuolana mixts., because of the

absence of both the defects mentioned above, present an abs. stability of their protective stratum and a practically perfect impermeability. Such mixts. are, therefore, the only ones rationally applicable at present to maritime construction or works intended to come into contact with sulfated waters.

ROBERT S. POSMONTIER (*C. A.*)

34. **Influence of additions of calcium sulfate or chloride on the shrinkage of cement.** A. GUTTMAN. *Zement*, 9, 310–3, 429–32(1920).—Addition of raw gypsum or $CaCl_2$ to portland, iron-portland, or blast-furnace cements cause them to swell so that the natural shrinkage is counteracted or only takes place after a long time. Cements so treated are especially adapted for use as mortars where it is desired that the joint should be nearly invisible.

(*C. A.*)

PATENT

35. **Burning lime.** N. WOLLAN AND KARL SANDE. Norw. 30,821, June 14(1920). Finely divided limestone is made to fall freely through gas heated to a high temp. (*C. A.*)

BOOK

36. **Zehn Jahre Portlandzement Prüfung.** HANISCH, AUGUST. Leipzig: Arthur Felix, 31 pp. M. 5. For review see *Z. angew. Chem.*, **34,** Aufsatzteil, 159(1921). (*C. A.*)

9

ACTIVITIES OF THE SOCIETY

New Members Received during September and October

Associate

Bales, Cecil E., Louisville Fire Brick Works, Highland Park, Ky.
Burt, N. P., Great Western Stove Co., Leavenworth, Kan.
Chesler, Isidor, 710 East 14th St., New York City.
Cole, Sanford S., Alfred, N. Y.
Doane, G. Earl, Poplar Bluff, Mo.
Handy, James O., Pittsburgh Test Laboratory, Box 115, Pittsburgh, Pa.
Jackson, Wynne L., 111 S. Kilpatrick Ave., Chicago, Ill.
Krak, J. B., 42 Hammond St., Jamaica, N. Y.
Lynch, Richard H., 8th and O'Donnell Sts., Baltimore, Md.
Montgomery, R. A., Springfield Paving Brick Co., Springfield, Ill.
Quay, Paul Q., 15620 Euclid Ave., East Cleveland, Ohio.
Rennieburgh, Cedric L., 625 W. Main St., Zanesville, Ohio.
Rodgers, Louis E., 30 N. LaSalle St., Chicago, Ill.
Rushmore, Murray, 120 West 8th St., Plainfield, N. J.
Stamm, Charles L., 212 W. 2nd St., Mt. Vernon, N. Y.
Wright, M. H., Tennessee Enamel Mfg. Company, Park Ave. and Railroad. West Nashville, Tenn.

Foreign Associate

Kanashima, Shigeta, Tokio Technical College, Asakusa, Tokio, Japan.
Maruyama, Junkichi, 7 Icchome, Gojotori, Chikko, Osaka, Japan.

Corporation

The Strong Manufacturing Co., Sebring, Ohio.
U. S. Metals Refining Co., Chrome, N. J.

AMERICAN CERAMIC SOCIETY

OFFICERS, 1921-1922

CORPORATION MEMBERS, 1920-1921

Abrasive Company
Acme Brick Company
Alexander Hamilton Institute
American Dressler Tunnel Kilns, Inc.
American Emery Wheel Works
American Encaustic Tiling Company
American Rolling Mill Company
American Terra Cotta & Ceramic Co.

Bausch & Lomb Optical Company
Beaver Falls Art Tile Company
Benjamin Electric Mfg. Company
Bird & Company
Brick and Clay Record
Buckeye Clay Pot Company
W. G. Bush & Company

Canton Stamping & Enameling Company
Carborundum Company
Champion Ignition Company
Champion Porcelain Company
Chicago Crucible Company
Colonial Company
Coonley Mfg. Company
Cortland Grinding Wheel Company
Crescent Refractories Company

Dings Magnetic Separator Company
H. L. Dixon Company
B. F. Drakenfeld & Company, Inc.
Dunn Wire Cut Lug Brick Company

East Liverpool Potteries Company
Edgar Plastic Kaolin Company
Elyria Enameled Products Company
Charles Engelhard, Inc.

Findlay Clay Pot Company
Edward Ford Plate Glass Company
French China Company
Frink Pyrometer Company

General Ceramics Company
W. S. George Pottery Company
Gillinder Brothers
Gleason-Tiebout Glass Company
Golding Sons Company

Hall China Company
Hanovia Chemical & Mfg. Company
Harbison Walker Refractories Company
Harker Pottery Company
Harshaw, Fuller & Goodwin Company
Homer-Laughlin China Company
L. J. Houze Convex Glass Company

Illinois Glass Company

Jefferson Glass Company
Johnson Porter Clay Company
Johnston Brokerage Company
Jones Hollow Ware Company

Kier Fire Brick Company
Edwin M. Knowles China Company
Knowles, Taylor and Knowles Company

Laclede-Christy Clay Products Company
Limoges China Company
A. J. Lindemann & Hoverson Company
Lindsay Light Company
Los Angeles Pressed Brick Company
Louthan Manufacturing Company

McLain Fire Brick Company
D. E. McNicol Pottery Company
Macbeth-Evans Glass Company
Maine Feldspar Company
Massillon Stone and Fire Brick Company
Matawan Tile Company
Maxf Grinding Wheel Corporation
Midland Terra Cotta Company
Mississippi Glass Company
Mitchell Clay Mfg. Company
Monongah Glass Company
Moore & Munger
Mosaic Tile Company

National Fireproofing Company
Niles Fire Brick Company
Norton Company

Ohio Pottery Company
Old Bridge Enameled Brick & Tile Co.
Onondaga Pottery Company
Owen China Company

Parker Russell Mining & Mfg. Company
Pennsylvania Pulverizing Company
Pennsylvania Salt Mfg. Company
Perth Amboy Tile Company
Pfaudler Company
Philadelphia Drying Machinery Company
Phoenix Glass Company
Pittsburgh High Voltage Insulator Co.
Pittsburgh Plate Glass Company
Portland Stove Works
Potters Supply Company
Product Sales Company

Reading Fire Brick Works
Reliance Firebrick & Pottery Co., Ltd.
Roessler & Hasslacher Chemical Company
Russell Engineering Company

Salem China Company
John H. Sant & Sons Company
Saxon China Company
Sebring Pottery Company
Smith-Phillips China Company
Square D Company
Standard Pottery Company
Standard Sanitary Mfg. Company
Star Porcelain Company
Stark Rolling Mill Company
Steubenville Pottery Company
Stockton Fire Brick Company
Streator Clay Mfg. Company
Strong Mfg. Company

Taylor, Smith & Taylor Company
R. Thomas & Sons Company
Trenton Flint & Spar Company

United States Glass Company
U. S. Smelting Furnace Company
Universal Clay Products Company

Veritas Firing System
Vitro Manufacturing Company
Vodrey Pottery Company

Wahl Company
Warwick China Company
Washington Brick, Lime & Sewer Pipe Co.
West End Pottery Company
Western Stoneware Company
Whitall-Tatum Company

JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Editor: E. W. Washburn; **Associate Editors:** L. E. Barringer, A. V. Bleininger, R. L. Clare, E. P. Poste, H. Ries, F. H. Rhead, R. B. Sosman, R. T. Stull, E. W. Tillotson

Vol. 4 **December, 1921** **No. 12**

EDITORIALS

GLASS DIVISION PREPARES RESEARCH MATERIALS

The research committee of the Glass Division of the Society has perfected a plan for providing glass of desired compositions and desired form for investigators in this field. The material will be supplied free of charge and no limitation as to the nature of the research will be imposed. The recipients of the material will be under no obligations except that of publication of the results of their investigations. The committee, however, requests that wherever possible the Journal of the American Ceramic Society be given preference in reporting the results. Persons who are interested are requested to address their inquiries to one of the following members of the Committee of Research: E. C. Sullivan, Corning Glass Works, Corning, New York; E. W. Washburn, University of Illinois, Urbana, Illinois; R. B. Sosman, Geophysical Laboratory, Washington, D. C.

This action of the Glass Division sets an example, which, with appropriate modifications might be followed by every division of the Society. Knowledge of where materials for research may be secured is not as widespread as it should be, and research workers in all ceramic lines will welcome an agency to whom inquiries can be directed and whose coöperation can be relied upon in securing such materials.

THE ST. LOUIS MEETING

The Twenty-fourth Annual Meeting of the American Ceramic Society will be held in St. Louis, February 27 to March 2, 1922, with headquarters at the Hotel Statler. St. Louis is an important center for refractories and heavy clay products, for enameled ware, glass and terra cotta and an unusually interesting series of inspection trips is expected. The program of papers for the sessions of the Society and its Divisions is in charge of Mr. R. D. Landrum, Chairman of the Committee on Papers and Program, care of The Harshaw, Fuller and Goodwin Co., Cleveland, Ohio, and titles of papers should be sent to him at an early date. Owing to the numerous undertakings which have been launched during the last year the coming meeting will be one of the most important ever held by the Society and a large attendance is expected.

ORIGINAL PAPERS AND DISCUSSIONS

A COMPARATIVE STUDY OF AMERICAN AND GERMAN QUARTZITES AS RAW MATERIALS FOR THE SILICA BRICK INDUSTRY[1]

By K. Endell

ABSTRACT

Properties determined.—Chemical composition, cone fusion temperatures, micro-structure in the raw state and after successive firings, and velocity of inversion on successive firings.

Comparative burning behaviors.—After a single firing to 1435°C the German erratic block quartzites of the tertiary age show a much greater expansion than the American quartzites. Hessian quartzite resembles the American.

Advantages of the German quartzites.—The use of the German erratic block quartzites for the manufacturing of silica brick of the highest quality is the more economical, both in preparation and burning costs, as compared with the American quartzites.

Introduction

As compared with fire-clay products, the silica refractories are growing in importance. Following the American example, Germany is also extending its utilization of silica brick to furnaces (with the exception of the Martin's furnace) in which heretofore only fire-clay refractories have been employed. This is due to the greater high temperature strength and greater thermal conductivity of silica as compared with fire-clay. The use of silica brick in coke ovens and of silica sections in the manufacture of illuminating gas will be recalled in this connection.

During the war there appeared in American scientific publications, several notable investigations dealing with quartzites

[1] Received Aug. 22, 1921.

and silica brick, among which those of Kenneth Seaver, J. Spotts McDowell, A. V. Bleininger, Donald W. Ross and H. Insley and A. Klein may be mentioned.[1]

From these investigations it is evident that the American silica brick industry employs a variety of quartzite different from that used in Germany. The variety employed in America is a fine grained quartzite, chiefly from the silurian or devonian ages, which in thin sections displays a closely intergrown mass of quartz granules without any bonding cement. In Germany, on the other hand, for the best quality of silica brick an erratic block quartzite of the tertiary age is still preferred. A thin section of this rock shows a structure composed of quartz granules with corroded edges, imbedded in a bonding cement.

The author showed in 1913[2] that an intelligent selection of quartzites for silica brick manufacturing could be made on the basis of a microscopic examination of the material, together with a determination of its rate of expansion on repeated firings. The purpose of the present investigation is to compare the American and German quartzites from this point of view. Through the kindly coöperation of Mr. Spotts McDowell of the Harbison-Walker Refractories Company of Pittsburgh and of Dr. Heinrich Koppers of Essen, I secured samples of the characteristic American quartzites of Medina, Baraboo and Alabama, together with some silica brick manufactured from them.

Chemical Composition of the Quartzites

The three American quartzites were compared with a Hessian quartzite, and with two typical German erratic block quartzites, one from Westerwald and one from Saxony. The chemical compositions and the cone melting temperatures of these six types of quartzites are shown in table I.

It is evident from these data that, as regards chemical composition, there are no essential differences among the six varieties

[1] Seaver, K., *Trans. Am. Instit. Min. Eng.*, **53**, 125(1916); McDowell, J. S., *Bull.*, 119; *Am. Instit. Min. Eng.*, Nov., **1916**; Bleininger, A. V. and Ross, D. W., *This J.*, **18**, 519–23(1916); Ross, D. W., Bureau of Standards, Wash., *Tech. Paper*, No. **124**; Insley, H. and A. Klein, *Ibid.*, No. **124**.

[2] Endell, K., "Über Silikaquartzite," *Stahl u Eisen*, 1913, Nos. **42** and **45**.

TABLE I—PERCENTAGE CHEMICAL COMPOSITIONS AND CONE MELTING TEMPERATURES OF THE QUARTZITES

<table>
<tr><th></th><th colspan="3">U. S. A.[1]</th><th colspan="3">Germany</th></tr>
<tr><th></th><th>Medina</th><th>Baraboo</th><th>Alabama</th><th>Westerwald</th><th>Saxony</th><th>Hesse</th></tr>
<tr><td>SiO_2</td><td>97.8</td><td>97.15</td><td>97.7</td><td>97.8</td><td>97.5</td><td>98</td></tr>
<tr><td>Al_2O_3</td><td>0.9</td><td>1.0</td><td>0.96</td><td>1.8</td><td>1.5</td><td rowspan="2">1.8</td></tr>
<tr><td>Fe_2O_3</td><td>0.85</td><td>1.05</td><td>0.8</td><td>0.4</td><td>0.5</td></tr>
<tr><td>CaO</td><td>0.1</td><td>0.1</td><td>0.05</td><td rowspan="2">0.1</td><td rowspan="2">0.3</td><td rowspan="2">0.2</td></tr>
<tr><td>MgO</td><td>0.15</td><td>0.25</td><td>0.3</td></tr>
<tr><td>Alkalies</td><td>0.4</td><td>0.1</td><td>0.3</td><td colspan="3">not determined</td></tr>
<tr><td>Cone-melting Temp.</td><td colspan="3">Cone 36 ≈ 1790°C</td><td colspan="2">Cone 35 ≈ 1770°C</td><td>Cone 36 ≈ 1790°C</td></tr>
</table>

[1] Data from K. Seaver, *op. cit.*

of quartzite. Only slight differences appear in the refractory powers as measured with Seger cones, doubtless due partly to the unreliability of this method in the case of such a highly viscous liquid as fused silica.

Microstructure

Photomicrographs were taken of thin sections of each material. Four of these are reproduced in figure 1. Those for the Baraboo and the Alabama quartzites are not given because they differ only slightly from that of the Medina. These three quartzites are non-micaceous and exhibit sharp, angular quartz grains, which, in the absence of bonding material, are closely intertwined, in part with re-entrant angles. A similar structure is exhibited by the Hessian quartzite, while that of the erratic block quartzites has an entirely different appearance.

A discussion of the origin of the latter varieties may be found elsewhere.[1] It is supposed that the silicic acid gel formed during

[1] Schubel, W., "Über Knollensteine u. verwandte tertiäre Verkieselungen," *Dissertation*, Halle, **1911**, p. 36.

Planck, A., "Petrographische Studien über tertiäre Sandsteine u. Quartzite," *Dissertation*, Giessen, **1910**, p. 43.

Endell, K., "Über die Enstehung tertiärer Quartzite im Westerwald," *Zentr. Mineralog.*, **1913**.

FIG. 1.—Photomicrographs of raw quartzite viewed under polarized light. Magnification ×110.

(a) Medina quartzite

(b) Hessian quartzite

Both quartzites display closely packed quartz grains without a binding cement.

(c) Erratic block quartzite from Saxony

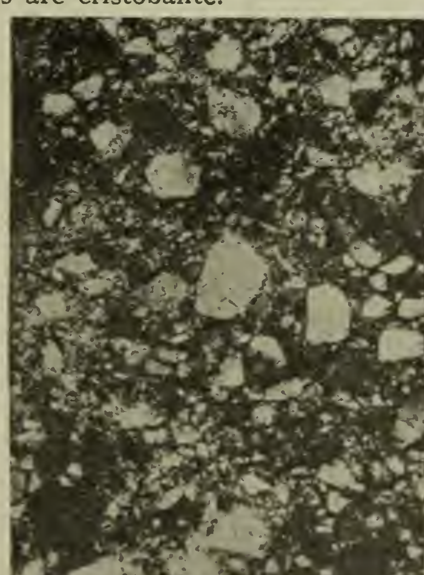
(d) Erratic block quartzite from Westerwald

Both quartzites display quartz grains with partially corroded edges which are embedded in a crypto-crystalline base of cement.

FIG. 2.—Photomicrographs of quartzites after a single firing to cone 15 (≈ 1435°C) in a porcelain kiln. Photographed under polarized light. Magnification × 110.

(*a*) Medina quartzite (*b*) Hessian quartzite

The greater part of the quartz crystals are still present. The black, apparently amorphous, spots are cristobalite.



(*c*) Erratic block quartzite from Saxony (*d*) Erratic block quartzite from Westerwald

The greater part of the quartz crystals has been transformed. The crypto-crystalline ground mass has been completely converted into cristobalite and shows black in the photograph. No tridymite can be detected.

the tertiary age, either as such, or after admixture with fine sand, underwent, in the course of geologic ages, a recrystallization through the opal stage to chalcedony and quartz. In accord with this theory of the origin of the Westerwaldian and Saxon quartzites of the erratic block type, we find these materials displaying clearly rounded and in part strongly corroded quartz granules seated in a crypto-crystalline cement base. This basal cement is composed of crypto-crystalline silicic acid and shows black in the photograph,—that is, it behaves almost like an amorphous body.

Sample pieces (about 50 cm. thick) of the various quartzites were calcined to cone 15 ($\approx$1435°C) in a porcelain kiln. Between cones 10($\approx$1300°C) and 14($\approx$1410°C) the firing was conducted at the rate of one cone per hour, while from cone 15 to cone 10, two hours were required. The kiln cooled from cone 15 to cone 10 in one hour, and thereafter, of course, still more slowly.

The photomicrographs (figure 2) taken from the calcined samples exhibited very marked differences which can be best discussed in connection with the curves of inversion velocity.

The Curves of Inversion Velocity of Quartzite on Repeated Calcinations to Cone 15 ($\approx$1435°C) in a Porcelain Kiln

In the selection of quartzite for the manufacture of silica brick it is desirable that most of the inversion shall complete itself during the first firing, that is, that the brick shall acquire the specific gravity, 2.33, belonging to the form of silica stable at the high temperature, (*i. e.*, either tridymite or cristobalite according to the firing temperature). In order to determine these velocity curves, the specific gravity of the powdered material was determined in pycnometers of 3 cc. capacity. The results obtained are shown in figure 3.

It is evident from these results that under the given conditions, the transformation of both of the German erratic block quartzites, even after only one calcination, is more complete than that of the American or Hessian materials. The same result is also apparent from the photomicrographs shown in figure 2. On the second calcination, the American quartzites exhibit a much greater expansion and almost attain the limiting values which were

reached by the erratic block quartzites in the first calcination. The behavior of the Hessian material is, however, not quite so satisfactory.

Photomicrographs of thin sections of the quartzite after the second and third calcinations were also made. In no instance could tridymite be recognized with certainty. Its absence, however, is easily understood since, owing to the lack of fluxing materials, the conditions for the formation of the metastable cristobalite were much more favorable. The presence of cristobalite after several calcinations was also demonstrated by means of dilatometric cooling curves.[1]

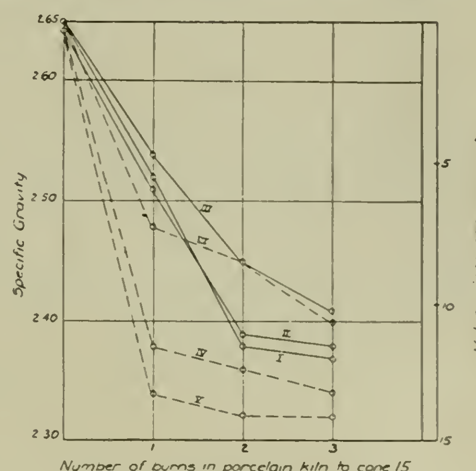


FIG. 3.—Curves of inversion velocity of the different quartzites on repeated burning in a porcelain kiln to cone 15 (≈ 1435°C). American quartzite, I, II, III; German quartzite, IV, V, VI.

Owing to the great uncertainties in working with quartzites no attempt was made to determine quantitatively the relative amounts of quartz, cristobalite and tridymite by the methods employed by the American investigators of silica brick.

Conclusions

1. The high temperature transformation of quartz into cristobalite takes place with the erratic block quartzites of Westerwald and Saxony much more rapidly than with the Medina, or Baraboo quartzites of America. The German quartzites of Hesse, however, resemble those of America.

2. Comparative studies of American and German silica brick have shown that the former, although composed of a quartzite which is less readily transformed than the German erratic block quartzites, frequently possess a lower specific gravity and consequently undergo a smaller subsequent expansion on heating to

[1] Cf. Endell, "Über Silikaquartzite," *Stahl u. Eisen*, l. c., figure 1.

1600 °C, than do the German brick. It is therefore evidently entirely possible to manufacture first quality silica brick from both types of quartzites by proper attention to preparation of the raw materials and to the time and temperature of burning.

Since the rate of transformation increases with the surface exposed it is important in the case of the slower types of quartzites to follow the American practice of fine grinding and longer subsequent burning. In this way the same final result is attained as with the more rapid types of quartzite which are almost completely transformed in a single burn. The manufacture of the highest quality silica brick from the slower types of quartzite is, therefore, primarily a question of burning costs.

Technische Hochschule
Charlottenburg, Germany

POROSITY: III. WATER AS AN ABSORPTION LIQUID

By Edward W. Washburn and Frank F. Footitt

ABSTRACT

Classes of absorption methods.—The ordinary immersion method has been shown by previous investigators to be unreliable. Simple immersion in low *vacuo* without boiling is also shown theoretically to be unreliable. An analysis of the results of previous investigators indicates the presence of unsuspected sources of error.

Effect of adsorbed gases upon dry weights of test pieces.—Dry air is shown to be without appreciable influence. Depending upon the humidity of the atmosphere, *adsorbed water vapor may cause errors up to 2 per cent* in the porosity value. Perfectly dry fired clay will remove water from conc. H_2SO_4 and from fused $CaCl_2$.

Saturation by boiling at atmospheric pressure.—A one hour's (and in one instance a 5 hours') boiling failed to saturate completely. On continued boiling the saturated weight increases linearly with the time and this in spite of the fact that appreciable quantities of dissolved materials are removed from the test piece by the hot water. This result is shown to be due to a gradual and continuous rehydration of the clay by the hot water. The error from this factor may amount to as much as 3% and the error from dissolved materials to as much as 2%, during a 3 hours' boiling. The nature of the dissolved material was determined.

Method of cooling the test piece.—It is recommended that the test piece be kept in a closed vessel over 95% sulphuric acid for several hours before its dry weight is taken.

Saturation procedure.—A vacuum method is described in which water may be employed as the saturation liquid under conditions where the above sources of error are reduced to a minimum. The method is *not* however recommended as *a primary standard.*

Necessity of a soaking period.—It is shown from theoretical considerations that *a soaking period is necessary* and methods are given for calculating and for measuring the minimum soaking period required for a given test piece and a given liquid of known penetrativity.

III. An Analysis of the Results and Conclusions of Previous Investigators

11. The Experiments of Beecher.—The only comparative studies of the different methods in use for measuring porosity by the absorption process which we have been able to find de-

scribed in the literature are those of M. F. Beecher[7] and of F. W. Walker, Jr.[8] In Beecher's investigation comparisons were made of the results obtained by the "immersion" method,[9] by the "boiling-in-air" method, by the "vacuum method," and by combinations of these methods.

Beecher's results with the immersion method show beyond question that this method can not be depended upon to effect *complete* saturation of a ceramic body even after long soaking. This confirms the results of other investigators[10] on this point, and demonstrates the inadequacy of this method for the purpose of securing accurate porosity data. This conclusion is moreover in entire harmony with the theory of the mechanism of saturation by immersion which has already been discussed.[11]

As regards the other two methods, Beecher reached the following conclusions:

> "Immersion in a vacuum showed slightly lower results on the average than the boiling treatment. From the data presented, it was decided that for ordinary laboratory work where the time element as well as accuracy is a factor, and where the results are for comparison only, within a given study, saturation by boiling for 45 minutes to one hour is sufficient for porosity and absorption determinations. Treatment with the vacuum alone does not offer better results."

From the data which he gives it is not clear that the vacuum which he employed was sufficient to boil the water. He states that the test pieces were "immersed and subjected to a vacuum of 29″ for three hours." Now under a vacuum of 29″ (*i. e.*, a pressure of 25 mm.) water will boil only if its temperature is maintained at 26°C, (about 78°F) and Beecher's paper contains no information concerning the temperature of the water in his experiments. If the water did not boil steadily, his experiments

[7] Beecher, *Trans. Am. Ceram. Soc.*, **18**, 73(1916).

[8] Walker, *Ibid.*, **18**, 446(1916).

[9] In the "immersion" method, a piece of the porous material is immersed in water for several hours and is then removed and weighed. On the assumption that all of the pores have been filled by water, the porosity is then calculable. In the so-called "boiling-in-air" method, the piece is boiled for a stated time in distilled water under atmospheric pressure. The procedure in the "boiling-in-vacuo" and "immersion-in-vacuo" methods is obvious.

[10] Ries, *Trans. Am. Ceram. Soc.*, **9**, 699(1907). Purdy and Moore, *Ibid.*, **9**, 693(1907). Walker, F. W., Jr., *op. cit.*

[11] See Part I, Sec. 6.

can scarcely be said to furnish a fair comparison of the two methods because the slow part of the absorption process is the last part, that is, the removal of the last traces of air from the pores of the body and this part of the process can obviously not be materially hastened by immersion under a vacuum insufficient to boil the liquid. A pump which maintains a vacuum of 29″ is quite good enough provided the water is kept warm enough to boil steadily. In the absence of any information concerning this point in the case of Beecher's experiments they can not, of course, be regarded as evidence of the superiority of the "boiling-in-air" method over that of "boiling-in-vacuo."

Furthermore, his conclusions that "where absolute accuracy is the important consideration, a combination of boiling, with the vacuum treatment, and a soaking period is the most effective means of saturation," will require modification in the light of some new information pointing to the existence of a hitherto apparently unsuspected source of error.

An analysis of his data as to the effect of a soaking period after boiling shows that, with the exception of one experiment[12] (which in the absence of any confirmatory experiments must be rejected because of its wide deviation from the others), the additional soaking period apparently produces on the average an increased absorption of only 0.18 ± 0.07 gram of water. Beecher states that his experimental procedure consisted in drying the test pieces with a soft towel and weighing them to a "tenth of a gram." With such a procedure, it might be doubted whether much significance should be attached to differences as small as 0.18 gram but for certain cases, theory indicates the necessity of a reasonable soaking period and this aspect of the subject will be more fully discussed below. (Sec. 29.)

12. Walker's Experiments.—Walker's experiments were in many respects similar to those of Beecher, although made upon biscuit wall tile, while Beecher employed grogged clay. Walker employed a vacuum of 28″ and evidently the water used was not warm enough to boil under this vacuum. It is thus clear that in neither of these investigations was the vacuum method given a really fair test.

[12] The 13th experiment recorded in his table II.

Walker, however, correctly suggests that the "boiling-in-vacuo" method, if properly carried out, *should* give the best results.[13]

In cases where it can not be carried out, Walker suggests a *five hours' boiling* at atmospheric pressure. As evidence that such a long period is necessary in order to insure complete removal of the air from the pores, he presents a graph which shows that the absorption of water increases *linearly* with the time. In view of the linear nature of this increase, there is evidently no assurance that the absorption is complete even at the end of five hours. As far as can be judged from the data presented, the absorption must continue to increase at the same rate, if the boiling is continued beyond five hours. On the evidence presented, therefore, it seems hardly justifiable to recommend the long boiling period of five hours.

It seemed to the writers that the results of Walker's experiments were rather to be interpreted as pointing to the existence of a hitherto unsuspected source of error in the "boiling-in-air" method, one which might prove so important *in certain classes of bodies* as to condemn the method entirely as a standard method for the determination of porosity values where a high degree of accuracy is sought. The present investigation had, therefore, as one of its first objects, the clearing up of the apparently anomalous behavior exhibited by the results of Walker's experiments.

IV. Preparation of the Test Pieces

13. **Preparing and Shaping.**—The body employed in the following tests was made from a common brick shale which was crushed with the aid of a jaw crusher and rollers, and then, without screening, was mixed with tap water until somewhat stiffer than a stiff mud brick. A 25-lb. batch was worked by hand on a marble slab, wedged into shape for the barrel of the briquette machine, and forced through the 1″ square die. The first trial was free from lamination and was wire-cut into four-inch

[13] But he implies that "expensive equipment" is essential. Such is, however, not the case. The method could have been successfully carried out with the equipment at his disposal, if water at a temperature of not less than 100°F had been employed. Judging from the boiling temperatures tabulated in Walker's paper, he was aware of this possibility, but for some reason, not obvious, he failed to make use of it.

pieces, fifty pieces being obtained from the batch. After air drying, the pieces were placed in a steam drier for 12 hours.

14. Firing.—An 8 × 16 × 2 inch slab was placed in the bottom of the kiln, and this was covered with a second slab supported by two bricks, thus forming a chamber in which the briquettes were set in 2 ranks of 3 high and 2 files, making 6 piles with 6 briquettes in a pile, or 36 in all.

The kiln was closed in the usual manner and the burn started with wood, followed by soft coal. The water smoking continued for 2 hours, the temperature being raised 50° per hour for 4 hours and held for 2 hours at 200°. Oxidation was complete at 700°. The temperature was then raised about 30° per hour and 12 samples were drawn at 950°. These were placed in hot sand and allowed to cool slowly. Twelve more samples were similarly drawn at about 1050°. At 1150° the last 12 samples were drawn, the total time of burning being about 31 hours.

15. Selecting and Preparing the Briquettes for Test.—From the briquettes prepared and burned as just described, three of each class were selected, that is, 3 drawn at 950°, 3 at 1050°, and 3 at 1150°. These were selected so as to be as free as possible from cracks and other imperfections. If any superficial cracks or holes were discovered, they were enlarged with a knife so as to be sure that no pockets were hidden beneath them. No cracked briquettes were employed. The entire surfaces of the 950° and 1050° briquettes were made as smooth and as uniform as possible, and all corners and edges rounded by polishing with sandpaper. In the case of the 1150° briquettes, this smoothing was done with the aid of a file, since the briquettes were too hard to be affected by the sandpaper. The nine briquettes prepared in this way were then placed in the drying closet and heated at 120° for six hours. It was first desired to ascertain the effect of the nature of the atmosphere upon the "dry weight" of the test pieces. This was carried out as described below.

V. Effect of Adsorbed Gases upon the "Dry Weight" of the Test Piece

16. Adsorbed Water Vapor.—Four desiccators were prepared, the first one containing "1.86 sp. gr." H_2SO_4, the second

52 per cent H_2SO_4, the third 33 per cent H_2SO_4, and the fourth one pure water. The relative humidity of the air in these four desiccators was approximately 0 per cent, 33 per cent, 67 per cent and 100 per cent, respectively. The briquettes were removed from the drying chamber at 120°, placed in the first desiccator and allowed to cool over the concentrated sulphuric acid. They were then weighed as rapidly as possible in order to obtain their approximate dry weights, after which they were heated to a second time to 120° and allowed to cool once more over the sulphuric acid and again weighed.

After the dry weights had been obtained in this way, the briquettes were transferred successively to the second and to the third desiccators, their weights being determined after remaining in each desiccator for 24 hours. They were finally placed in the fourth desiccator over the pure water where they were allowed to remain for 120 hours, weighings being made every 24 hours. The results of this study are displayed in table I, the gains in weight in each instance being expressed in terms of per cent of the weight of the dry briquette.[14]

From these results it is evident that cooling in a dry atmosphere is essential to the most accurate results. Allowing the briquette to cool in the room or to stand for some time in the room may introduce errors in the "dry weight" up to as high as one per cent, depending upon the nature of the body, the humidity of the air at the time, and the period elapsing before the "dry weight" is taken.

17. **Adsorbed Air.**—In order to determine the amount of dry air which would be adsorbed by the body employed in the tests, three red-hot briquettes were transferred directly from the furnace to a previously heated hard glass tube. This tube was then evacuated to an X-ray vacuum and allowed to cool until its weight was constant to 0.1 mg. for 24 hours. Dry air was then admitted and the weight again determined as soon as pressure equalization had

[14] Cf. the results of Mellor and Holdcroft (*The Chemical Constitution of the Kaolinite Molecule*. Staffordshire "Collected Papers," **1**, 287. Griffin and Co., London, 1914) on the hydroscopicity of dry clay powder; and those of Day and Allen (*Am. J., Sci.*, **19**, 93(1905)) on powdered minerals, which show that orthoclase powder will adsorb, from the atmosphere of the room, moisture up to some 0.7 per cent of its weight.

TABLE I—ILLUSTRATING THE INFLUENCE OF ATMOSPHERIC HUMIDITY UPON "DRY WEIGHT" OF CLAY BODIES

Drawing temperature	Number of briquette	Weight after 24 hours in 0% saturated air	Percentage gain in weight on standing						
			24 hours in 33% saturated air	24 hours in 67% saturated air	24 hours in 100% saturated air	48 hours in 100% saturated air	72 hours in 100% saturated air	96 hours in 100% saturated air	120 hours in 100% saturated air
	19	80.370	0.071	0.14	0.27	0.32	0.42	0.44	0.46
950°	18	81.528	.075	.14	.30	.39	.44	.46	.49
	17	76.147	.076	.14	.31	.40	.44	.48	.51
		Average	**0.074**	**0.14**	**0.30**	**0.37**	**0.43**	**0.46**	**0.49**
	29	84.061	0.080	0.17	0.57	0.87	0.97	1.08	1.12
1050°	31	82.698	.073	.17	.55	.85	.92	.97	1.00
	30	83.936	.057	.11	.34	.52	.55	.55	0.59
		Average	**0.070**	**0.15**	**0.49**	**0.75**	**0.81**	**0.87**	**0.90**
	22	83.149	0.008	0.02	0.02	0.05	0.05	0.06	0.07
	23	83.262	.007	.02	.03	.05	.06	.07	.07
1150°	30	84.517	.001	.004	.006	.009	.01	.01	.02
		Average	**0.005**	**0.015**	**0.019**	**0.036**	**0.04**	**0.05**	**0.05**

taken place. This process was repeated daily for 9 days. At first a slight inrush of air occurred each time the tube was opened to the atmosphere. This gradually diminished, and at the end of 9 days equilibrium had been reached and the weight no longer changed. The total increase in weight during this period was only 6 mg. in a total weight of 437 grams. The weight-in-air thus obtained was reduced to *vacuo*, and the calculated weight-in-vacuo thus obtained agreed with the observed weight-in-vacuo within the experimental error. In some additional experiments in which an attempt was made to estimate the amount of adsorbed air by releasing it into a vacuum positive results were obtained, but the amounts found were too small to affect appreciably the dry weight of a briquette.

It is thus evident that no significant error can arise from adsorbed air in the case of burned clay bodies.

We know, however, that many porous materials and powders are capable of taking up large quantitites of air and other gases.[15] This is true, for example, in the case of the colloidal silica developed by Patrick[16] for war purposes, also in the case of certain minerals such as the zeolites and chabazites which after dehydration were found by Friedel[17] to absorb 1.8 per cent of their own weight of dry air. It can not be said with certainty, therefore, that *all* ceramic bodies will not adsorb appreciable quantities of air, although this will probably be true of most of them after they have been fired above red heat. (Cf. Sec. 68 below.)

18. **Adsorption of Water Vapor from "Dry" Air.**—Although not capable of adsorbing significant quantities of air, burned clay bodies have a great avidity for moisture, as is evident from the experiments described in the Section 16. This was illustrated in a still more striking manner by the three briquettes employed in the above experiment. After removal from the hard glass tube, they were placed immediately in a desiccator and allowed to stand for 12 hours over $CaCl_2$. They were then weighed and found to

[15] For bibliography and review of this subject see Scheringa, K., *Pharm. Weekblad.*, **56**, 94(1919).

[16] Patrick, *J. Ind. Eng. Chem.*, **2**, 97(1919); *J. Am. Chem. Soc.*, **42**, 947 (1920).

[17] Friedel, Ch., *Compt. rend.*, **122**, 1006(1895).

have gained 9 centigrams or 0.04 per cent in weight. The following results were obtained when "1.86 sp. gr." sulphuric acid was used in place of $CaCl_2$ in the desiccator: Gain in weight for briquettes drawn at 950°, 0.02 to 0.04 per cent; 1050°, 0.08 to 0.11 per cent; 1150°, 0.05 to 0.06 per cent; 48 hours in desiccator.

It is evident from these results that a perfectly dry piece of burned clay is a more powerful drying agent than calcium chloride or sulphuric acid, since it will take water away from either of these materials.[18] The gain in weight under these conditions, while interesting as a phenomenon, is, of course, too small to have any practical significance in connection with porosity determinations.

VI. Comparison of the "Boiling-in-Vacuo" and the "Boiling-in-Air" Methods for Determining Porosity

19. Boiling-in-Vacuo.—The dry briquettes prepared as described above were placed in a filter bottle connected with a separatory funnel filled with distilled water. The air pump employed was a small rotary high vacuum pump driven by a motor. The filter bottle containing the briquettes was first evacuated until the pressure fell to less than a millimeter. The stop-cock of the separatory funnel was then opened and the water, which had been previously boiled under a vacuum, was admitted until the briquettes were covered. The vacuum pump was continued in operation and the briquettes *boiled* at room temperature in this way for one hour, after which they were removed, wiped with a *wet* cloth and weighed. The percentage increase in weight due to the absorption of water in this process is shown in column 5 of table II.

After weighing, the briquettes were transferred to a porcelain casserole, covered with water, and boiled in the open air for one hour, after which they were allowed to cool in the water and were

[18] The $CaCl_2$ used was taken from a bottle of the granulated material supplied for desiccator use. The sulphuric acid was the ordinary "C. P. 1.86" grade. Both products doubtless contained small amounts of water, and it was this water which was removed by the briquettes. Similar results to those given above are reported by Hillebrand, W. F. (*Geol. Survey Bull.*, 422, 69(1916)), in the case of a powdered mineral which, after dehydrating at 280°, gained 1½ per cent on standing in a desiccator over sulphuric acid.

TABLE II—COMPARISON OF THE "BOILING-IN-VACUO" AND THE "BOILING-IN-AIR" METHODS FOR DETERMINING THE POROSITY OF BURNED CLAY BODIES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Drawing temperature	Number of briquette	Dry weight, grams	Weight after boiling 1 hour at 25°	Per cent gain in weight	Weight after boiling an additional hour at 100°C	Additional per cent gain	Weight after drying *in vacuo* at 100° followed by 1 hr's. boiling at 100°C	Per cent gain over original dry weight	Weight after two additional hours' boiling at 100°C	Additional per cent gain	Total per cent gain	Dry weight after removal of water *in vacuo* at 110°	Weight of material dissolved from clay body. Per cent	Net increase in dry weight of clay. Per cent.
950°	31*	82.440	102.022	23.8	102 .030	0.01	101.714	23.4	102.051	0.4	23.8	(81.500)		
	18	80.410	101.306	26.0	101.329	0.03	100.695	25.2	101.272	0.7	25.9	81.757		
	34	79.438	100.051	26.0	100.095	0.06	98.603	24.1	99.906	1.7	25.8	79.465		
Total		**242.29**	**303.38**	**25.2**	**303.45**	**0.03**	**301.01**	**24.2**	**303.23**	**0.9**	**25.1**	**242.72**	**0.43**	**1.3**
1050°	5	83.914	102.730	22.4	102.763	0.04	102.211	21.8	102.801	0.7	22.5	84.187		
	29	81.433	99.985	22.8	100.044	0.07	99.683	22.4	100.010	0.4	22.8	81.699		
	15	82.260	99.957	21.6	100.030	0.10	99.571	21.1	100.056	0.5	21.6	82.532		
	28	81.534	100.075	22.8	100.167	0.11	99.549	22.1	100.157	0.8	22.9	81.705		
Total		**329.14**	**402.75**	**22.4**	**403.00**	**0.08**	**401.01**	**21.9**	**403.02**	**0.6**	**22.3**	**330.12**	**0.17**	**0.47**
1150°	39	84.330	89.876	6.59	89.957	0.09	89.318	5.91	89.849	0.6	6.5	84.443		
	3	86.836	88.312	1.71	88.287	....	88.283	1.67	88.277	...	1.7	87.193		
Total		**171.17**	**178.29**	**4.15**	**178.24**	**0.03**	**177.60**	**3.76**	**178.12**	**0.3**	**4.1**	**171.64**	**0.083**	**0.36**

* Omitted in computing the value given in column 15. Probably low, owing to loss of small chip at some time during handling.

then removed, wiped with a wet cloth as before and weighed again. The additional increase in weight brought about by this process was practically nothing, as shown by the figures in column 7 of table II. In other words, the pores of the brick had apparently become completely filled with water during the vacuum treatment.

20. Boiling at 100°C.—It was next desired to study the rate of absorption of water by the briquette when boiled at 100°. For this purpose the briquettes used in the previous experiment were dried at 100° *in a vacuum* for one hour, after which they were transferred to a large porcelain casserole and boiled in water under atmospheric pressure for *one hour* and then, after cooling, were removed, wiped with a *wet* cloth and weighed. The per cent gain in weight due to the absorption of water in this process is shown in column 9 of table II. On comparing these figures with those of column 5, it will be noticed that they are uniformly lower. *In other words, one hour's boiling in the open air is not sufficient to completely fill the pores of the briquette with water.*[19] An additional two hours' boiling at 100° was then carried out, and the resulting additional gain in weight is given in column 11, the total gain resulting from the three hours' boiling being shown in column 12. On comparing the figures of column 12 with those of column 5, it will be seen that they are substantially identical. In other words, three hours' boiling in the open air was required in order to obtain the same weight of the water-filled body as was obtained after one hour's boiling in the vacuum.

All of the water in which the briquettes had been boiled was carefully collected, filtered, and evaporated to dryness. A considerable amount of dissolved material was obtained in this way, the weight of the material dried at 110° being shown in column 14 of table II. The briquettes were also dried again *in vacuo* at 100° for 4 hours and weighed. These second dry weights are shown in column 13 of the table. On comparing these

[19] A similar result has been found by Loomis, G. A. (*This J.* **1**, 393 (1918)), with fire-clay. The Report of the American Ceramic Society's Committee on Standards, Jan. 3, 1918, prescribed 45 minutes' boiling at atmospheric pressure for porosity determinations, but in a subsequent report issued in Feb., 1920, the time was increased to 2 hours.

second dry weights with the first dry weights, it will be seen that on the average they are decidedly larger, in spite of the fact that appreciable quantities of material were dissolved out of the briquettes during the water treatment. If we add to the second dry weights, the weights of the materials dissolved from the briquettes and subtract from the sum the original dry weights, we obtain the *net increase in weight of the clay* as a result of the foregoing treatment. This net increase expressed in per cent is shown in column 15.

21. **Nature of the Dissolved Material.**—In order to determine the approximate chemical composition of the material dissolved from the briquettes, three fresh briquettes of each class were boiled for four hours at 100° and the water was filtered, evaporated, and the residue partially analyzed. The results of these analyses for the 1050° class are shown in table III.

TABLE III—ANALYSIS OF THE WATER-SOLUBLE RESIDUES OBTAINED FROM THE BOILING EXPERIMENTS

Weight of residue dried at 110° = 0.29 gms.

Determination	Grams	Weight per cent
Ignition loss	0.0093	3.2
SiO_2	.0296	10.2
$Fe_2O_3 + Al_2O_3$	.0035	1.2
CaO	.0181	6.2
MgO	None	
Sulphates	None	
Alkalies (as chlorides)	0.2	

VII. Effect of Prolonged Immersion in Hot Water

22. **Purpose of the Experiment.**—The increase in the "dry weight" of the test piece shown by the data in table II apparently points towards a gradual and steady rehydration of the clay when it is boiled in water at 100°. If such a rehydration actually occurs, of the magnitude indicated, it would evidently explain the results obtained by Walker. In order to secure additional evidence on this rehydration hypothesis, two series of experiments were carried out.

23. **Immersion at 100°.**—In one of these a 1050° briquette was heated to redness, allowed to cool in a high vacuum, dry air

admitted, and the dry weight of the briquette determined without removing it from the vacuum tube. It was then allowed to stand in a desiccator, first over $CaCl_2$ and then over water, and the increase in weight observed. It was finally subjected to prolonged boiling at 100°, the dissolved matter collected and weighed, and the briquette finally dried for 3 hours *in vacuo* at 100°, weighed, ignited to red heat and weighed again. The results are shown in table IV and in figure 2.

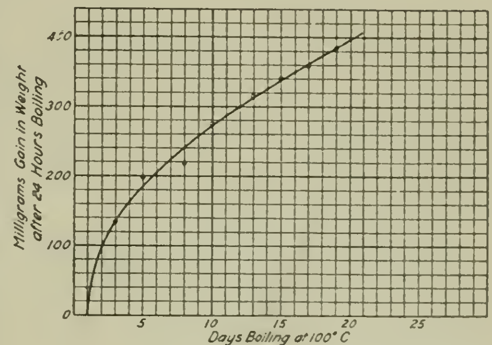


FIG. 2.—Rate of water absorption on prolonged immersion at 100°C.

TABLE IV—REHYDRATION OF BRIQUETTE NO. 32 (DRAWN AT 1050°)

Dry weight after heating to 1000° and cooling in high *vacuo* 81.625 gms.

Increase in weight (expressed in per cent of dry weight) produced by

Standing 12 hrs. over calcium chloride	0.04
Standing 72 hrs. over water	.47
Standing 96 hrs. over water	.53
Boiling 24 hrs. in water at 100°C	22.4
Boiling 72 hrs. in water at 100°C	22.6
Boiling 456 hrs. in water at 100°C	22.9
Loss of dissolved material	−0.36
The above treatment followed by drying *in vacuo* at 100° for 3 hours	.91
Plus material dissolved	1.27
The above treatment followed by two ignitions at red heat	0.2

24. Immersion at 200°.—For the experiments on the effect of prolonged immersion at 200°C, two briquettes were heated in an electric furnace to 1000°, allowed to cool in a desiccator over $CaCl_2$ and their dry weights determined. They were then placed in a porcelain dish and covered with distilled water. The dish was placed in an autoclave containing an excess of water, and this was heated to 200° and kept at that temperature for 15 hours.

After cooling, the autoclave was opened, the briquettes removed, the fragments collected in a filter, and the water evaporated to dryness to obtain the dissolved material. All the material thus obtained was dried at 120° and weighed. The increase in weight over the original dry weight amounted to 1.5 grams or 0.87 per cent.

25. **Discussion of the Results.**—As a result of these experiments it seems to be established beyond question that "burned" clay slowly rehydrates in contact with water, the extent of the rehydration naturally being dependent upon time, temperature, and the nature and condition of the body.

Since the experiments here described were completed, there has been published an account of an investigation by Laird and Geller[20] on the rehydration of clay. They found that clays calcined at low temperatures (600° to 800°), could be rehydrated by prolonged heating with water at 200–270°. This also agrees with results secured by Mellor and Holdcroft[21] with kaolinite dehydrated at 600°.

We may, therefore, conclude that the "boiling-in-air" method for determining the porosity of burned clay products does not fulfill the requirements of a "*standard reference method*" as outlined in the introduction.[22]

VIII. Interpretation of the Results and Their Bearing upon the Determination of Porosity

26. **The Sources of Error, their Magnitudes and Significance.**—The magnitudes of the various sources of error studied in this investigation may be conveniently summarized for comparison by tabulating them in terms of the percentage error which they produce upon the corresponding porosity values. For example, if the true porosity is 20 per cent and the value found by an inaccurate procedure is 20.2 per cent, the corresponding error in the porosity itself is evidently 1 per cent. The results of this

[20] Laird and Geller, *This J.*, **2**, 828(1919).

[21] Mellor and Holdcroft, *op. cit.*, p. 283.

[22] The American Society for Testing Materials in its "1921 Standards" prescribes five hours' boiling in the open air in determining the porosity of drain tile (p. 558) building brick (p. 578) and clay sewer pipe (p. 591). In the case of refractory materials, however (p. 623), a four hours' immersion in kerosene of known density at 25°C under a vacuum of 24 in. is prescribed. This degree of vacuum is not sufficient to boil the kerosene, and consequently will not materially shorten the time required for *completely* filling the pores. It might, however, cause some change in the density of the kerosene and possible consequent error, due to evaporation of the more volatile constituents. The error from this source is probably not significant for practical purposes, however.

method of representation are shown in table V and figure 3, positive values indicating that the error in question gives too large a value for the porosity, and negative values, the reverse.

In making any deductions from the results shown in table V the following considerations should be kept clearly in mind: (1) The values given are approximate only, but their order of magnitude may be taken as substantially correct. (2) They apply only to the particular body investigated, and must not be taken as representative of ceramic bodies in general. Other bodies may be expected to show either larger or smaller errors from the factors in question, depending upon the character of the body. With these facts in mind, we may proceed to a consideration of the significance of the data displayed in the table.

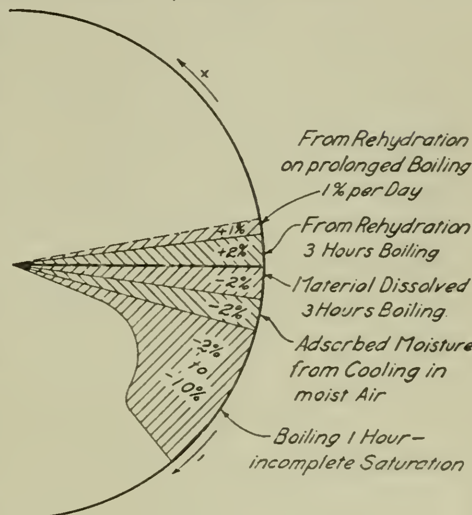


FIG. 3.—Typical magnitudes of various sources of error in the "boiling-in-air" method.

TABLE V—ILLUSTRATING THE PERCENTAGE ERROR IN A POROSITY DETERMINATION, PRODUCED BY EACH OF THE FACTORS INDICATED

Factor	Drawing temperature 950°	1050°	1150°
Cooling 12 hrs. over $CaCl_2$ or H_2SO_4	About —0.2 per cent		
Cooling 24 hrs. in 33% sat. air	—0.3	—0.3	—0.06
Cooling 24 hrs. in sat. air	—1.	—2.	—0.2
Boiling 1 hr. at 25°C		Taken as zero	
Boiling 1 hr. at 100°	—4.0	—2.2	—2 to —10
Boiling 3 hrs. at 100°:			
(*a*) From rehydration	+1.7	+0.76	+2.0
(*b*) From material dissolved	—1.7	—0.76	—2.0
Prolonged boiling at 100°:			
(*a*) From rehydration (See figure 3)	—	About +1 per cent per day after the 1st day	
(*b*) From material dissolved	Up to —2 per cent, probably all during the 1st two days		

27. **Method of Cooling the Test Piece.**—The most accurate method of obtaining the true dry weight of the test piece is, of course, to cool it in a perfect vacuum, as evident from the data in table IV. The error introduced by cooling in a desiccator over sulphuric acid or calcium chloride is, however, not large enough to have any significance as far as porosity measurements of most ceramic products are concerned. In fact, it may be doubted whether the adsorption of a small quantity of water vapor is really a source of error at all. The great avidity displayed by dry clay for water vapor shows that the first layer of water taken up from the surrounding atmosphere is very strongly held by the clay surface. This most strongly held adsorption layer is perhaps only one molecule deep[23] all over the exposed surface, and the water in this layer may have a density very much greater than unity, a density in fact corresponding to that which would be the result of a large increase of pressure.

Since it is probable that nearly all of such a compression would be borne by the first one or two layers of molecules next the surface, it is not unreasonable to suppose that the porosity results obtained would be fully as accurate, if this first surface layer could be adsorbed before the "dry weight" of the test piece is taken, and its weight, which would be small, neglected in comparison with the total weight of absorbed water. Since, however, there is no way of telling in advance *exactly* what condition of drying will give just this layer, neither more or less, the best that can be done in general is to prescribe some arbitrary but uniform method of cooling the test piece.

In order to obtain some information upon which to base the formulation of a suitable procedure for cooling the test piece preparatory to taking its dry weight, the following experiments were carried out:

A disk (15 cm. in diameter and 5 mm. thick) of a white ware body fired at cone 8 and having a porosity of about 60 per cent,

[23] Cf. Langmuir, *J. Am. Chem. Soc.*, **40**, 1361(1918) and **39**, 1848(1917); also McGavack and Patrick, *Ibid.*, **42**, 968(1920); Lamb and Coolidge, *Ibid.*, **42**, 1165(1920); and Washburn, "Introduction to the Principles of Physical Chemistry," 2nd Ed., 425–30. McGraw-Hill Book Co., N. Y., 1921.

was cleaned, weighed (133.422 gms.), heated to 1000°, transferred to a vacuum desiccator over 95 per cent H_2SO_4, allowed to cool 12 hours, and again weighed. Its "dry weight" obtained in this way was 132.860 ± 0.002 grams, and it gained very rapidly while in the balance case, although the latter had a dish of sulphuric acid in it. The dry piece was then placed over water, in order to saturate itself with water vapor, and weighed again. This time it *lost* weight very rapidly while in the balance case, its weight, as nearly as could be determined, being 133.450 grams.

The piece was finally returned to the vacuum desiccator containing the 95 per cent sulphuric acid and weighed at intervals to determine the rate of loss of adsorbed water.

In four hours its weight had fallen to 132.950 grams. Twenty hours later it had fallen to 132.930 grams, and an additional 48 hours' standing decreased it to 132.910 grams, after which it remained constant for 48 hours at 132.910 grams or 0.055 gram more than its original "dry weight." This 0.055 gram of adsorbed water is evidently held very firmly since it is not removed in 5 days by 95 per cent sulphuric acid.

The result of the above experiments suggests the following as a sufficiently exact procedure for securing the "dry weight" of the test piece for porosity determinations when water is used as the absorption liquid:

Place the test piece in a desiccator over 95 per cent sulphuric acid and allow it to remain there until it has reached "constant weight." If, as is ordinarily the case, the weighings are made to the nearest decigram, then it is evident from the above experiments that, for a very porous body, a few hours (2 or 3) in the desiccator is sufficient for the attainment of "constant weight." Previous to being placed in the desiccator, the test piece should be in contact with moist air for a short time in order that it may have an opportunity to adsorb its surface layer of water. If, after removal from the furnace, it is allowed to stand in the room until completely cold, this will ordinarily suffice to give it the requisite amount of adsorbed water. Evacuation of the desiccator will, of course, shorten the time required to attain constant weight.

28. The Vacuum Method of Porosity Measurement.—If the water absorption method is to be used at all as a permissible method for determining porosity where accurate results are desired, the vacuum method is obviously *the most trustworthy* procedure which can be employed. The most accurate method of carrying it out is obviously the following:

Place the test pieces, whose dry weights have been determined, in the vacuum vessel and evacuate the air until, on closing the connection to the pump, the manometer reading remains constant. Then close the connection to the pump and admit enough air-free, *cold*, distilled water to cover the test pieces. Disconnect the pump, and immediately break the vacuum. Allow the test pieces to soak until the water has completely penetrated the pores; then remove the test pieces, "dry" by wiping with a *very damp* towel or with some non-absorbent material,[24] and weigh. Evaporation during weighing may be prevented by inclosing the test piece in a weighing tube.

In order to carry out the method in the above manner, a good vacuum pump is necessary. The degree of vacuum required in any given case may be computed as follows: Let B be the barometric pressure, A be the fractional accuracy desired in the porosity value, and p be the pressure required in the vacuum vessel. Then from the laws of gases we find, for the extreme case of no channel pores,

$$p \ngtr AB \tag{1}$$

Thus if the accuracy required is 1 per cent of the porosity itself, then for p we find 7.6 mm. or 0.3 inch. With the above procedure, employing *cold* water and avoiding boiling or stirring, it is evident that both rehydration and solution would be reduced to a minimum, since the temperature is low and any dissolved material can escape from the test piece only by diffusion, which is a relatively slow process. The method could thus probably be safely employed even with under-burned bodies, if desired. Nothing is to be gained by employing hot water.

[24] Or better, by completely immersing the piece for a moment in mercury. This method was suggested by Prof. C. W. Parmelee. It has the advantage of automatically removing the surface water, as well as the water from those surface pores which are large enough to be penetrated by the mercury, thus eliminating the personal equation from the procedure.

If the pump available is not powerful enough to give the vacuum required for the above procedure, then the best method of operation is simply to *boil* the test piece *in vacuo* for the minimum period necessary[25] to effect complete saturation within the desired limit of accuracy. It is impossible to specify a length of time for this boiling process which will apply to every case.

29. Necessity for a Soaking Period.—In the above procedure no definite specification as to soaking period is given, nor is such an exact specification possible in general. Time is required for the water to penetrate the smallest pores of the body, and the smaller and more numerous these pores are, the greater will be the time required for complete saturation. The driving pressure behind the water is atmospheric pressure plus the surface tension pressure, and for very small pores is not sufficient to produce complete penetration except after very long periods of soaking.

The theory of the rate of penetration of porous bodies by liquids has been discussed by the senior author in another publication.[26] This theory shows that the amount of liquid which penetrates a porous body is proportional to the square root of the time of soaking and to the square root of the ratio, $\frac{\gamma}{\eta}$ of the surface tension of the liquid to its viscosity, for all cylindrical pores except those of molecular dimensions. Thus, if the pores of a briquette filled to the extent of 10 per cent in 2 minutes, it would require at least 3 hours and 20 minutes' soaking in order to fill them completely, assuming them to be of uniform dimensions.

The time required for complete penetration can be greatly reduced by the use of external pressures of several hundred atmospheres, as has been shown by Cude and Hullett,[27] and for very dense bodies with excessively fine pores, the use of such pressures offers the only hope of securing accurate porosity values by any absorption process. Equipment for producing such pressures is not ordinarily available in ceramic laboratories at the present time, however, and fortunately for many cases met with in actual

[25] To be found by trial. See Sec. 30*b* below.

[26] Washburn, "The Dynamics of Capillary Flow," *Phys. Rev.*, **17**, 280 (1921).

[27] Cude and Hullett, *J. Am. Chem. Soc.*, **42**, 400(1920).

practice, it is not important to include in the measured porosity these very small pores.[28]

Until further data are available, therefore, it would seem best to prescribe a somewhat arbitrary soaking period, which can be ascertained in the following manner:

30. Determination of the Minimum Soaking Period.—(*a*) *By Calculation.*—The time required for water to penetrate a distance, l, along a small cylindrical capillary is given by the expression[29]

$$t = \frac{l^2}{rz} \qquad (2)$$

where r is the radius of the capillary and z $\left(= \frac{\gamma}{2\eta}\right)$ is the *coefficient of penetrance* or the *penetrativity* of the liquid. For water at room temperature

$$z = \frac{74}{0.02} = 3700 \text{ cm./sec.} \qquad (3)$$

For l we may safely write $\frac{1}{2}\, l_{max}$, where l_{max} is the length of the longest straight line wholly within the test piece. The value of r would depend upon the character of the body and the accuracy demanded. Thus for common clay products we might write $r = 0.5 \times 10^{-4}$ cm., that is, we would be satisfied as soon as all pores, with diameters not less than 0.001 mm., were filled with the liquid. With these assumptions equation (2) becomes

$$t = \frac{4l^2_{max}}{3} \qquad (4)$$

Thus for a briquette 4 in. long, we would have $l_{max} = 12$ cm. and hence, $t = 192$ sec. $= 3.2$ minutes.

With a material such as electrical porcelain for high tension insulators, it is necessary to take account of pores of much smaller diameter probably down to 10^{-5} mm. which is about a hundred

[28] Such materials as high tension electrical insulators, spark plug bodies, etc., of course, constitute exceptions to this statement, and the results of Cude and Hullett, referred to above, point to the desirability of employing a high pressure equipment for porosity studies on such bodies, or better the substitution of a gas in place of the liquid as the pore filling agent. This latter method will be described in the sixth paper of this series.

[29] Washburn, *op. cit.*, p. 280.

times molecular dimensions. Since the soaking time varies inversely as the pore diameter, the soaking time would be multiplied 100 fold, if pores as small as 10^{-6} mm. were included. Thus, for the briquette used in the above example, this would mean a soaking time of 5 hours, at least, thus emphasizing the necessity of employing high pressures when determining with accuracy the porosity of highly vitrified bodies by the absorption method.

(*b*) *By Direct Experiment.*—The calculated value obtained as described above is a minimum value only, because the calculation takes no account of the possible presence of pocket pores or pores whose diameters increase toward the interior of the body. Such pores would fill more slowly than the cylindrical pores. The actual soaking period required can be determined by suspending the immersed piece from the arm of a sensitive balance and noting the time required for it to attain its maximum weight. This maximum weight can, if desired, be determined in advance by the method which will be described in the sixth paper of this series.

31. Boiling at Atmospheric Pressures.—This method is evidently not sufficiently reliable for a standard reference method. In the cases studied, a one hour's boiling failed to produce complete saturation by from 2 to 10 per cent. Three hours' boiling gave the correct result, but only because the loss of weight due to dissolved material (1 to 2 per cent) just compensated for the gain in weight due to rehydration. Since there is no way of predicting in advance what period of boiling is necessary in order that these two errors shall just cancel each other, it is evident that the method should be rejected entirely as a *general standard*. There are, of course, many cases where it can be safely employed and will give results quite accurate enough for the purpose in hand. In any case where it is so employed, however, evidence that the errors are in fact negligible for the purpose in hand should be available. In this connection the following experience with the "boiling-in-air" method is worthy of mention. A standard size test piece of a stoneware body after firing to cone 10 was boiled in distilled water for 5 hours under atmospheric pressure. After removal and weighing it was found to have absorbed an amount of water corresponding to a porosity of 3 per cent. The actual porosity

of this same test piece was, however, later shown to be 15 per cent.

Part IV of this paper will deal with the use of petroleum products as absorption liquids.

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POROSITY IV: THE USE OF PETROLEUM PRODUCTS AS ABSORPTION LIQUIDS

By Edward W. Washburn and Elmer N. Bunting

ABSTRACT

Advantages of petroleum products.—Avoidance of: slaking, chemical reaction, adsorption, and solvent action; but longer soaking time is required.

Paraffine and vaseline.—Materials having high fluidity when hot, and comparatively low fluidity when cold, permit surface of saturated test piece to be brought to definite and reproducible condition with all surface pores full. Paraffine may be used but vaseline is preferable because it undergoes no change of phase on cooling.

Procedure and results.—A saturation procedure is described and comparative results given.

Density and penetrativity of vaseline.—Sp. gr. $\frac{23°}{4°}$ 0.8730, $\frac{32°}{4°}$ 0.8684, $\frac{42°}{4°}$ 0.8624. Penetrativity between 100° and 200°C = $0.063\ (t - 30)^2$ cms./sec. A *penetratimeter* for determining the penetrativity of liquids is described.

IX. Introduction

32. **Present Practice.**—In order to avoid the slaking action which water has on clay in the raw state, it is customary to substitute kerosene in place of water in measuring the porosity of raw clay bodies. In order to saturate the body with the kerosene, a 12-hours' soaking is prescribed in the "Tentative Methods" of the American Ceramic Society.[31] The American Society for Testing Materials[32] recommends the use of kerosene in place of water for determining the porosity of refractory products, and prescribes a 4-hours' soaking in kerosene at 25°C under a vacuum of 24″.

So far as we have been able to discover, the above references practically cover the literature with regard to the use of petroleum products as absorption liquids. The remaining literature adds nothing of importance to the subject, and there seem to

[31] "Rep. of the Comm. on Stands.," p. 14, 1918.

[32] A. S. T. M., "1921 Book of Standards," p. 623.

be no conclusive data available from which the efficiency of the method can be judged.

33. **Advantages and Disadvantages.**—For use as the absorption liquid, the obvious advantages of a petroleum product, over water, are the following: (1) absence of slaking action on raw clay, (2) little, if any, solvent action on the constituents of the body, (3) no tendency to combine chemically with the constituents of the body, and (4) much less tendency to be adsorbed on the surface.

The disadvantages doubtless vary somewhat with the particular material employed, and require investigation before their nature and magnitude will be definitely known in each case. The following disadvantages and possible sources of error in the use of such a liquid as kerosene, however, seem to be obvious.

(1) There is no evidence that simple immersion at room temperature and at atmospheric pressure will effect complete saturation in any reasonable time. Judging from the behavior of water in this respect, a simple immersion process would certainly not be very accurate.

(2) The rate of penetration of kerosene into a clean pore is much less than that of water. The ratio $\frac{t_w}{t_k}$, of the immersion times required in order to give the same degree of penetration in the cases of water and of kerosene, respectively, would be (cf. Sec. 29 above) $\frac{t_w}{t_k} = \frac{z_k}{z_w} =$ about 0.05,[33] that is, the penetrativity of water is about 20 times that of kerosene at room temperatures.

(3) Boiling at atmospheric pressure would obviously require the use of a still provided with a return condenser, and a gradual change in density due to decomposition ("cracking") occurs under these conditions. Furthermore, the fire risk associated with such a procedure would be a decided disadvantage.

34. **Purpose of the Investigation.**—It seemed to the writers

[33] This value for the relative penetrativities of these two liquids was determined in this laboratory by G. E. Sladek, using a penetratimeter of our own design. (See Sec. 37 below.) The above conclusions hold only for clean pores, such as those of a fired body. In pores which were contaminated with any material of a greasy nature the behaviors of the two liquids in this respect might be reversed.

that all of the advantages obtained by using kerosene in place of water might perhaps be secured, without the concurrent disadvantages, by employing a petroleum product which possesses a considerable degree of stiffness at room temperatures but attains a high degree of fluidity at the temperature of boiling water. The use of such a product would have the additional important advantage, lacked by every fluid material, of making possible a perfect cleaning of the surface of the test piece without the danger of removing any of the absorption material from the pores. This latter advantage would be especially important, for example, in the case of bodies with large pores.

X. Paraffine

35. Paraffine as an Absorption Material.—An initial investigation of paraffine as an absorption material was carried out, the procedure being as follows:

A supply of air-free paraffine was prepared by boiling it *in vacuo* at about 100° for several hours, and then allowing it to solidify completely *in vacuo*. A quantity of this paraffine, sufficient to cover the test pieces when melted, was placed in the vacuum vessel together with the weighed test pieces. After evacuating, heat was applied until the liquid paraffine attained a temperature of about 200°. The vacuum was then broken, and after a soaking period,[34] the contents of the vessel were allowed to cool to room temperature. The test pieces were then cut out of the block of paraffine, cleaned and weighed. The "effective density" of the paraffine was then determined by repeating the above experiment with a glass-stoppered pycnometer bottle substituted in place of the test pieces.

The above procedure obviously assumes that the thermal expansion of the test pieces is the same as that of the glass composing the pycnometer bottle which is indeed approximately the case. The error arising from this assumption will probably not exceed about one per cent of the porosity for most ceramic products, and the paraffine method is thus sufficiently reliable for many purposes. For a "*standard reference method*," how-

[34] The relative penetrativity of paraffine, in terms of water at 22° is 0.092 at 65°, 0.39 at 185°, and 0.45 at 215°C.

ever, it is desirable that even this degree of uncertainty shall not be involved. It was, therefore, decided to experiment with a material which possessed a considerable fluidity even at room temperature, but which was stiff enough so that it would not flow appreciably under the influence of gravity. Vaseline seemed to possess the desired characteristics, and it was therefore chosen for investigation.

XI. Vaseline

36. Preparation of the Vaseline.—Two liters of filtered vaseline (Chesebrough) were placed in a four-liter flask and boiled *in vacuo* (temp. 100°) for several hours, in order to eliminate any dissolved air or volatile constituents which may have been present. It was then allowed to cool *in vacuo*.

37. The Penetrativity of Vaseline.—The penetratimeter employed is shown in figure 4. It was manufactured from a capillary tube 0.5 mm. in diameter and 100 cm. long, by coiling it as shown and sealing on a glass stop-cock. The instrument was first standardized with water and, after cleaning and drying, was mounted in a bath of liquid vaseline, as illustrated in the figure. It was immersed until the end A was about 5 mm. below the surface of the liquid, the end B being about the same distance above the surface. As soon as temperature equilibrium was attained the stop-cock was opened and the stopwatch started. When the meniscus in the capillary reached a mark on the end B, the watch was stopped. The penetrativity of the vaseline is then equal to that of water, multiplied by the ratio of the time of penetrance of water to that of vaseline.

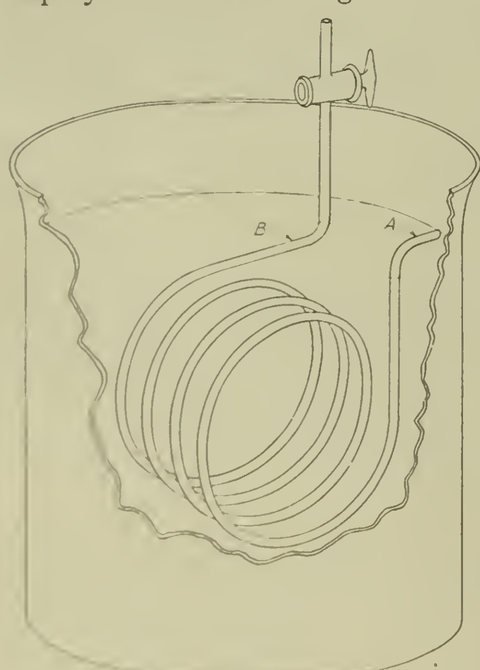

FIG. 4.—Penetratimeter for measuring the relative penetrativities of liquids.

The results between 100° and 200°C are expressed by the equation

$$z = 0.063(t - 30)^2 \text{ cms./sec.} \qquad (5)$$

38. The Specific Gravity of Vaseline.—The procedure was exactly the same as that described below (Sec. 47) except that a 50-cc. specific bottle was substituted for the test pieces. The specific gravity results are displayed in table VI and are expressed by the equation

$$d = 0.0203(46.8 - t) \qquad (6)$$

valid between 15° and 45°C.

Table VI—The Specific Gravity of the Vaseline

Temperature C	23°	32°	42°
Specific gravity	0.8730	0.8684	0.8624

XII. Experimental Comparison of Water and Vaseline as Saturating Liquids

39. Preparation of the Test Pieces.—Two well-burned briquettes of a common brick clay and a piece of porous white ware tile were selected and, after cleaning and smoothing as described in section 43 below, were heated to 1000°C, cooled over 95 per cent H_2SO_4, and weighed in closed weighing tubes.

40. Saturation of the Test Pieces.—The test pieces were first saturated with water at room temperature by means of the preferred procedure described in section 47 below. They were then removed, wiped lightly with a damp cloth, and weighed in closed weighing tubes.

The saturated test pieces were dried slowly at 100° *in vacuo*, followed by a short ignition at 1000° and were then cooled as before and their "dry weights" taken a second time. They were then saturated with vaseline, using the procedure described in section 47 below.

41. The Results.—The pore volume of each test piece as determined by the two methods is shown in table VII. It is evident that the results obtained with vaseline are uniformly about 2.3 per cent higher than those obtained with water. If this difference is significant, and it probably is, the results obtained with the vaseline are clearly to be given the greater weight,

TABLE VII—COMPARISON OF WATER AND VASELINE AS SATURATION LIQUIDS

Material	Dry weight, grams		Pore volume in cc.		
	Original	After removal of water	With water	With vaseline	Diff. per cent
Briquette No. 1	83.987	83.988	8.22	8.40	2.2
Briquette No. 2	89.113	89.115	9.15	9.41	2.7
Porous tile	26.191	26.193	4.48	4.54	1.3

since, with the knowledge which we have of the chemical and physical properties of the class of hydrocarbons to which vaseline belongs, it is difficult to imagine any source of error which would cause vaseline to give results *higher* than the true values, while it is not difficult to understand how the results obtained with water should be low by the amounts indicated.

This, of course, does not mean that the results obtained with the vaseline are necessarily the correct values, since they also may be too low, owing to incomplete filling of all the pores. However, judging from certain other experiments with this type of body, it seems probable that the above results for vaseline are close to the correct porosity values of the test pieces used (cf. Sec. 68 below). With certain close textured stoneware bodies, however, it can be readily shown that neither water nor vaseline (nor any liquid, for that matter) will give correct porosity values except after weeks or months of soaking, and with such bodies the required soaking time is materially greater for vaseline than for water; that is, the results obtained with vaseline tend to be lower than those obtained with water. These experiments will be presented in detail in the sixth paper of this series.

42. **Comparative Advantages of the Water and Vaseline Methods.**—When carried out with cold water, the water absorption method will not be attended by any error due to rehydration. Furthermore, if the regular procedure recommended below is followed, the danger of loss of soluble materials is reduced to a minimum, owing to the short immersion period and as much avoidance of stirring, as possible.

The vaseline method, of course, possesses neither of these sources of error. Its other advantage over the water method is the definite and constant surface condition which can be attained and accurately reproduced when the pores are filled with a viscous grease. This is especially important in the case of a body (such as "Nonpareil" brick, for example) which has large surface pores which could not be kept evenly filled during weighing, if the absorption material were very fluid at room temperatures. As a general rule, therefore, the vaseline method may be used to advantage whenever the accuracy desired is such as to require careful attention to the surface condition of the piece after removal from the absorption vessel or whenever errors due to the action of water on the body are to be feared. Owing to the long soaking time required the method is, however, not a satisfactory one to use with bodies having a considerable volume of very small pores.

To be continued

EARTHENWARE BODIES AND GLAZES[1]

By H. H. Sortwell

ABSTRACT

Effect of body composition on crazing.—Six bodies of each of 2 standard clay compositions were prepared with variable clay and flint content and after biscuiting at cone 8 were glazed with 21 earthenware glazes and glost fired at cones 4 and 6. The results indicated that the variability of the silica content of clays would not be great enough to produce crazing in a well-balanced glaze.

Effect of proportion and composition of frit.—A standard whiteware glaze was compounded in 6 different ways and several other glazes in 2 ways. It was found that the method of compounding had no effect on crazing but it affected the gloss and fusibility. Increase in the percentage of material fritted increased the gloss and fusibility. With the same percentage of frit the best glost and highest fusibility were obtained when the flint and part of the clay were included in the frit.

Effect of some variations in glaze composition.—Substitution of CaO by Na_2O, pound for pound, as well as direct addition of Na_2O increased crazing, improved gloss and increased the fusibility. Direct addition of feldspar increased crazing slightly and diminished gloss, but did not noticeably affect the fusibility. Substitution of $1^1/_2$ parts of feldspar for one part of flint to maintain the same fusibility increased crazing and diminished gloss. Direct addition of CaO improved gloss, increased fusibility and slightly reduced crazing.

Introduction

The occasional occurrence of crazing in the manufacture of white earthenware or semi-porcelain is the cause of the loss of many dollars annually. In nearly all plants crazing occurs intermittently and from causes which are difficult to detect. It was thought that occasional reduction in the silica content of the clays used might be one of the causes of crazing.

Since a variety of glazes was desired for this study, the effects of variation in the percentage and composition of the frit, and the effects of some variations in glaze composition were also investigated.

[1] Received April 2, 1921. Published by permission of the Director, U. S. Bureau of Standards.

Experimental

The bodies shown in table I were ground in ball mills six hours, filter-pressed, and wedged by hand for jiggering into discs $3^1/_2$ inches in diameter and $^1/_4$ inch thick. All of the bodies worked well in jiggering except 6 and 12, those of lowest clay content, which were a little short. The discs were burned to cone 8 in a small down-draft gas-fired kiln in 24 hours. The absorptions of the discs averaged from 4.3% to 6.3%.

TABLE I—BODIES

	1	2	3	4	5	6
English Ball Clay.............	18.5	17.2	16.0	14.8	13.5	12.3
Florida Kaolin................	9.2	8.6	8.0	7.4	6.8	6.2
English China Clay............	32.3	30.2	28.0	25.8	23.7	21.5
Maine Feldspar................	14.0	14.0	14.0	14.0	14.0	14.0
Flint.........................	26.0	30.0	34.0	38.0	42.0	46.0
	7	8	9	10	11	12
English Ball Clay.............	11.5	10.8	10.0	9.2	8.4	7.6
Tenn. Ball No. 5..............	8.1	7.5	7.0	6.5	5.9	5.4
Florida Kaolin................	9.2	8.6	8.0	7.4	6.8	6.2
English China Clay............	22.0	20.5	19.0	17.5	16.1	14.6
N. C. Kaolin..................	9.2	8.6	8.0	7.4	6.8	6.2
Maine Feldspar................	14.0	14.0	14.0	14.0	14.0	14.0
Flint.........................	26.0	30.0	34.0	38.0	42.0	46.0

With the exception of A, all of the frits were melted in crucibles and poured into water. Frit A was fired in a sagger in the bisque kiln to cone 8. The frits are shown in table II.

TABLE II—COMPOSITION OF FRITS

	A	B	C	D	E	F	G	H	K
Flint..........	24.0	6.30	....	24.0	18.0	...	...	...	...
Feldspar.......	...	..	15.6	...	...	21.00	13.30	18.10	21.00
Borax.........	4.38	4.38	4.38	4.38	4.38	4.38	18.50	18.50	18.50
Boric Ox.......	9.07	9.07	9.07	9.07	9.07	9.07	...	...	...
China Clay.......	2.33	2.33	...	...	...	...	...	...	...
Red Lead......	...	..	...	17.40	8.80	5.73	...	...	3.38
Whiting.......	1.07	1.07	...	...	...	...	...	...	...
Soda Ash......	...	..	...	...	...	...	...	3.76	...

TABLE III—BATCH WEIGHTS OF GLAZES

	Frit used														
	A	B	C	D	E	F	G	H	K	Feldspar	Flint	China clay	Whiting	White lead	Zinc oxide
1	34.0	..	..	..	..	..	..	..	..	34.0	..	3.6	15.0	19.7	3.5
2	..	16.3	..	..	..	..	..	..	..	34.0	17.7	3.6	15.0	19.7	3.5
3	..	..	23.0	..	..	..	..	..	..	18.4	24.0	5.9	16.1	19.7	3.5
4	..	..	..	48.4	..	..	..	..	..	34.0	..	5.9	16.1	..	3.5
5	..	..	..	..	34.0	..	..	..	..	34.0	6.0	5.9	16.1	9.75	3.5
6	..	..	..	..	..	34.0	..	..	..	13.0	24.0	5.9	16.1	13.25	3.5
7	..	..	..	..	..	..	23.0	..	..	20.7	24.0	5.9	12.0	19.7	3.5
8	..	..	..	..	..	..	..	30.0	..	15.9	24.0	5.9	8.0	19.7	3.5
9	..	..	..	..	..	..	..	30.0	..	15.9	24.0	5.9	..	19.7	3.5
10	..	..	..	..	..	..	23.0	..	..	20.7	24.0	5.9	..	19.7	3.5
11	..	..	23.0	..	..	..	..	..	..	18.4	24.0	5.9	..	19.7	3.5
12	..	..	..	..	34.0	..	..	..	..	34.0	6.0	5.9	..	9.75	3.5
13	..	..	..	..	..	..	..	30.0	..	29.4	15.0	5.9	..	19.7	3.5
14	..	..	..	..	..	..	23.0	..	..	41.4	10.0	5.9	..	19.7	3.5
15	..	..	32.0	..	..	..	..	..	..	51.4	..	5.9	..	19.7	3.5
16	..	..	..	..	..	34.0	..	..	..	46.0	..	5.9	..	13.25	3.5
17	..	..	..	..	..	34.0	..	..	..	46.0	..	5.9	16.1	13.25	3.5
18	..	..	..	..	..	34.0	..	..	..	51.0	..	5.9	..	13.25	3.5
19	..	..	..	..	..	..	23.0	..	..	25.7	24.0	5.9	12.0	19.7	3.5
20	..	..	..	..	..	..	23.0	..	..	48.4	10.0	5.9	..	19.7	3.5
21	.	..	..	..	..	..	..	..	34.0	40.7	10.0	5.9	..	15.9	3.5

The glazes (tables III and IV) were ground in ball mills, passed through a 150 mesh lawn, and applied to the discs fairly heavily by dipping. Two glost burns were made, cone 4 in 18 hours and cone 6 in 18 hours, the results of which are shown in tables V and VI.

BUREAU OF STANDARDS, WASHINGTON, D. C., APRIL 22, 1921
(Empirical Formulas)

TABLE IV—GLAZES

	K_2O	Na_2O	CaO	PbO	ZnO	Al_2O_3	B_2O_3	SiO_2
1	0.173	0.032	0.456	0.217	0.122	0.238	0.271	2.30
2–6	Same as one							
7	.175	.138	.344	.219	.124	.240	.276	2.32
8	.177	.243	.233	.222	.125	.243	.279	2.35
9	.230	.318	...	.289	.163	.317	.361	3.06
10	.266	.211	...	.334	.189	.366	.417	3.54
11	.317	.059	...	.399	.225	.437	.498	4.22
12	.317	.059	...	.399	.225	.437	.498	4.22
13	.295	.290	...	.265	.150	.375	.331	2.79
14	.368	.182	...	.288	.162	.452	.359	3.01
15	.478	.045	...	.305	.172	.570	.380	3.05
16	.478	.045	...	.305	.172	.570	.380	3.05
17	.292	.027	.390	.186	.105	.350	.232	1.87
18	.496	.044	...	.294	.166	.388	.367	3.16
19	.196	.135	.335	.214	.120	.263	.267	2.43
20	.398	.173	...	.274	.155	.483	.343	3.15
21	.398	.173	...	.274	.155	.483	.343	3.15

TABLE V—RESULTS OF CONE 4 GLOST BURN

1. Excellent commercial glaze. No crazing.
2. Underfired. Texture and gloss very poor. No crazing.
3. Underfired. Texture and gloss poor. No crazing.
4. Excellent glaze. No crazing.
5. Fair glaze. No crazing.
6. Fair glaze, but not as good as 5. No crazing.
7. Excellent glaze but crazed on bodies of 26, 30 and 34% flint.
8. Good gloss but crazed on all bodies.
9. Good gloss, but crazed on all bodies. Crazed more than 8 and gloss was not as good.
10. Poor gloss and crazed on bodies of 26, 30 and 34% flint. Crazed less than 9 and gloss was not as good. Crazed a little more than 7 and gloss was not as good.
11. Underfired. Poor gloss and texture but no crazing. Gloss was not as good as 10 nor 3.
12. Poor gloss but better than 11. No crazing.
13. Fair gloss but crazed badly on all bodies. Crazed more than 9 and gloss was not as good.

TABLE V (*Continued*)

14. Poor gloss and crazed on all bodies. Crazed more than 10 and gloss was not as good.
15. Poor gloss and crazed on all bodies of less than 46% flint. More crazing than 11 and gloss was not as good.
16. Fair gloss. Crazed on all bodies of less than 46% flint. Better gloss than 15.
17. Fair gloss. Crazed about the same as 15, but fusibility and gloss were improved.
18. Poor gloss and crazed on all bodies of less than 46% flint. More crazing and poorer gloss than 15.
19. Fair glaze but crazed on all bodies of less than 42% flint. Crazed more than 7 and gloss was not as good.
20. Poor gloss. Crazed on all bodies. Crazed more than 14 and gloss was not as good.
21. Fair gloss but crazed the same as 20.

TABLE VI—RESULTS OF CONE 6 BURN

1. Excellent commercial glaze. No crazing.
2. Very poor gloss. No crazing.
3. Poor gloss. No crazing.
4. Excellent commercial glaze. No crazing.
5. Good glaze. No crazing.
6. Fair glaze. No crazing.
7. Excellent glaze. Crazed on bodies of 26 and 30% flint.
8. Excellent glaze. Crazed on bodies of 26, 30 and 34% flint.
9. Good gloss. Crazed on all bodies of less than 38% flint.
10. Good glaze. Crazed on bodies of 26 and 30% flint.
11. Poor gloss. No crazing.
12. Fair gloss. No crazing.
13. Fair gloss. Crazed on all bodies of less than 42% flint.
14. Poor gloss. Crazed on all bodies of less than 42% flint.
15. Poor gloss. Crazed on bodies of 26 and 30% flint.
16. Fair gloss. Crazed on bodies of 26 and 30% flint.
17. Good gloss. Crazed on bodies of 26, 30 and 34% flint.
18. Poor gloss. Crazed on bodies of 26 and 30% flint.
19. Good glaze. Crazed on bodies of 26 and 30% flint.
20. Poor gloss. Crazed on all bodies of less than 42% flint.
21. Poor gloss. Crazing same as 20.

Effect of Variation in Body Composition on Crazing

The two original bodies used in this study were fairly typical of American factory practice, one being high in English china clay and English ball clay, and the other high in domestic clays, reducing the amount of imported clays used. The flint content

is 34% and the feldspar 14% in both bodies. From these two bodies, 3 and 9, two series were laid out maintaining the feldspar constant and replacing clay by flint through a range of from 26% to 46% flint, as shown in table I.

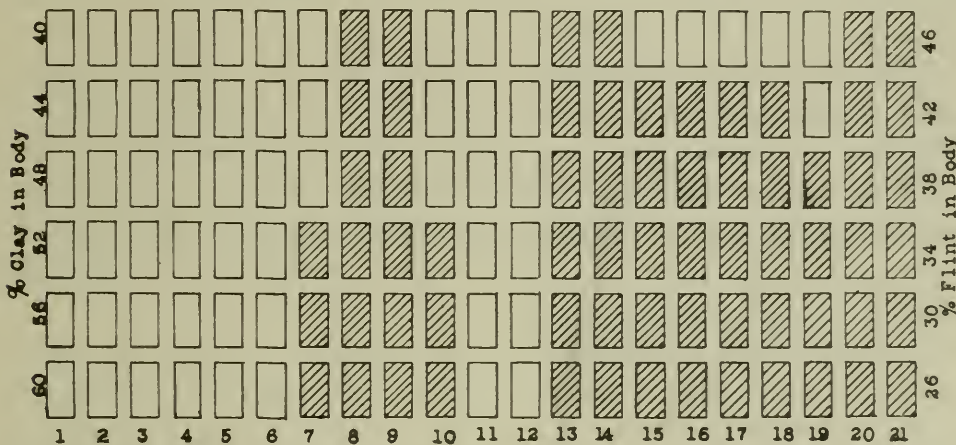

FIG. 1.—Earthenware bodies and glazes—Cone 4, cross-hatching denotes crazing.

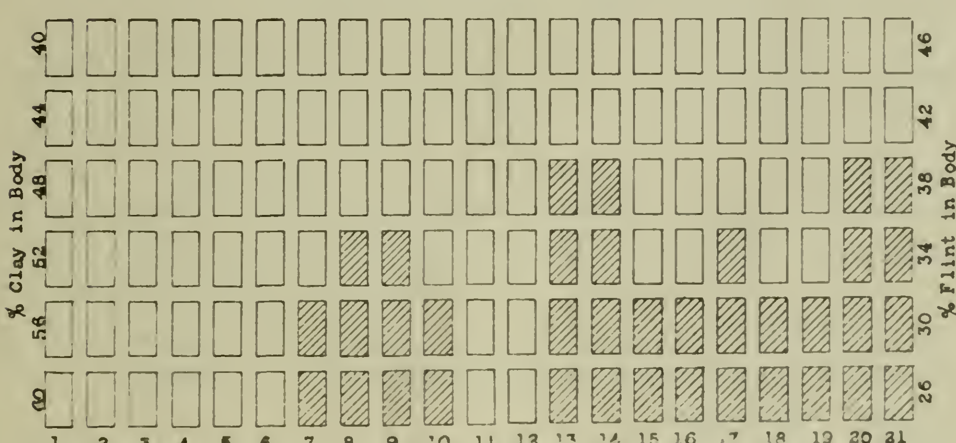

FIG. 2.—Earthenware bodies and glazes—Cone 6, cross-hatching denotes crazing.

From a study of figures 1 and 2, which show the extent of crazing of the 21 glazes on these bodies, the following points are noted.

The higher the percentage of flint in the body with a proportionate decrease in clay content, the fewer the number of glazes crazing on the body. The mesh of the crazing also decreased with increase

in flint. This agrees with the work of Seger,[1] Hecht,[2] Purdy,[3] and Ashley.[4] If the manufacturers of earthenware could overcome the mechanical difficulties in the forming of the ware, brought about by increasing the percentage of flint in the body at the expense of the clay, it is evident that the tendency for crazing to occur would be reduced.

The crazing decreased directly with the increase in flint content, there being no sharp difference noticed in the vicinity of 30% to 34% flint, in which range practically all of the bodies now in use lie.

There was no difference in the crazing in the two series due to the two different clay combinations used. Variation in the kinds and amounts of clays used does affect crazing but it was not studied in this investigation.

The difference in crazing due to variation in clay and flint content is so gradual that it is doubtful if reduction in the silica content of the clays from time to time would cause the occasional outbreaks of crazing occurring in most potteries. The standard glaze in all its variation in method of compounding did not craze even on the bodies of only 26% flint content.

Effect of Proportion and Composition of Frit in a Given Glaze

The standard whiteware glaze, laboratory No. 1, may be considered typical of those in common use in this country. The frit was made in saggers and fired in the bisque kiln. This glaze was compounded in six ways as shown in tables II and III. Since these frits, with the exception of A, were designed for use in the ordinary hearth frit kiln, they were chosen to maintain the proper fusibility instead of by pound for pound substitutions or substitution by chemical equivalents.

Frit A is the original frit used in factory practice. Frit B was obtained simply by reducing the amount of flint in the composition. In frit C, the whiting, china clay and flint were eliminated and sufficient feldspar used to render the frit insoluble. Frit D is the original frit without the whiting and china clay and with the

[1] "The Collected Writings of Herman A. Seger," pp. 575–576.

[2] Hecht, H., *Tonind.-Z.*, 1897.

[3] Purdy, Ross C., *Trans. Am. Ceram. Soc.*, **7**, 79(1905) and **13**, 157(1911).

[4] Ashley, Harrison E., *Ibid.*, **13**, 259(1911).

addition of all the lead oxide in the glaze. This frit was made to determine the effect of a larger percentage of frit in the glaze. Frit E is also a flint bearing frit giving the same percentage of frit as that used in the original glaze. Frit F is a similar frit in which feldspar is used in place of the flint. The fusibility was kept uniform by using slightly more feldspar than flint and reducing the amount of lead oxide. The frits were all found to contain less than three per cent soluble material by the method employed by Blumenthal.[1]

Other examples of the same glaze compounded in two ways are glazes 11 and 12, 15 and 16, and 20 and 21.

The following summary may be made of the study of these results:

1. The way in which the glazes were compounded had no noticeable effect on crazing but had a great effect on fusibility and gloss.

2. Increase in the percentage of frit increased fusibility and improved gloss.

3. With the same percentage of frit, the most fusible glazes with the best gloss were obtained when the more refractory ingredients of the glaze (flint and part of the clay) were included in the frit. This left less thermal work to be done in the glost kiln.

4. In changing from a sagger frit to a frit-kiln frit, if the same glaze is to be used, the frit composition should be made more fusible by the addition of fluxes rather than by taking out part of the refractory ingredients.

Effect of Some Variations in Glaze Composition

Replacement of Calcium Oxide by Sodium Oxide.—Glaze 7 is the same as 3 with part of the CaO replaced by an equal weight of Na_2O. Glaze 8 is the same with a still further replacement of this kind. Substitution of CaO by Na_2O caused crazing, increased the gloss, and made the glazemorefusible.

Direct Addition of Sodium Oxide.—Glazes 11, 10, and 9 differ only in the Na_2O content and the variation in the frits necessary

[1] Blumenthal, George, *This J.*, 3, 152(1920).

to introduce the required amounts of this ingredient. Addition of Na_2O improved the gloss, increased the fusibility and increased crazing.

Direct Addition of Feldspar.—Glaze 19 is the same as 7 with 5% feldspar added to it, and 20 is 14 plus 7% feldspar. These changes caused a slight increase in crazing and diminished the gloss but had no very noticeable effect on fusibility.

Substitution of Feldspar for Flint.—To maintain the same fusibility in substituting feldspar for flint, the substitution was not made on a pound for pound basis, but approximately one and one-half parts of feldspar were added in place of one part of flint left out. To glaze 9, 13.5 parts of feldspar were added in place of 9 parts flint to make glaze 13. To glaze 10, 20.7 parts of feldspar were added in place of 14 parts of flint to make glaze 14. To glaze 11, 33 parts of feldspar were added in place of all the flint, 24 parts, to make glaze 15. Replacement of flint by feldspar in this manner had no noticeable effect on fusibility but increased crazing and diminished gloss.

Direct Addition of Calcium Oxide.—In the glazes studied there were four cases showing the effect of the direct addition of CaO to a glaze. These are 3 and 11, 7 and 10, 8 and 9, and 16 and 17. The addition of CaO improved the gloss, increased the fusibility and reduced crazing slightly.

Effect of Raising Temperature of Glost Fire

Examination of Figs. 1 and 2 shows that raising the temperature of the glost kiln from cone 4 to cone 6 reduced the crazing in all cases where crazing had occurred at cone 4. This has long been recognized and is one method of reducing the tendency to craze; in fact, this change has been made in several plants recently for this purpose.

At cone 6 the gloss and maturity of the poorer glazes of cone 4 were improved. None of the glazes studied showed signs of overfiring at cone 6.

The author wishes to thank Mr. Homer F. Staley for advice and suggestions in the laying out and studying of the work.

Bureau of Standards
Washington, D. C.
April 22, 1921

CERAMIC ABSTRACTS

List of Principal Journals Abstracted

The following list contains the principal journals which publish material of ceramic interest. The information given has been obtained directly from the publishers and is correct as of July 1, 1921. Similar information concerning journals not here listed can be obtained from the list published annually in the last number of *Chemical Abstracts.*

Title and order. Black-face type used in the full titles given, designates that part of the title which is the official abbreviation of the periodical. The names of the periodicals are listed in the alphabetical order *of their abbreviations.*

Dates of appearance. The following symbols are used: *a.* (annual), *sa.* (semiannual), *sq.* (semiquarterly), *q.* (quarterly), *bm.* (bimonthly), *m.* (monthly), *sm.* (semimonthly), *bw.* (biweekly), *w.* (weekly), *sw.* (semiweekly), *irr.* (irregular).

Price. All prices given, unless mention is made to the contrary, are for subscriptions or single copies delivered in the United States. Prices in parentheses are for single copies; prices not so enclosed, unless otherwise stated, are for *one year's* subscription. F—franc, £—pound, s—shilling, d—penny, M—mark.

Publisher. Publisher's name and address, or the name and address of the person to whom orders may be sent, appear in italics.

Example. Full title of periodical, The American Journal of Science. Abbreviation, Am. J. Sci. Monthly. Price of a year's subscription, $6.00 in the United States. Price of a single copy, $0.50. Subscriptions may be sent to The American Journal of Science, c/o Edward S. Dana, New Haven, Conn.

American **J**ournal of **Sci**ence, The. *m.* $6 ($.50). *Edward S. Dana, New Haven, Conn.*

American **Mineral**ogist, The. *m.* $3 ($.30). *Albert B. Peck, Mineralogical Lab., University of Mich., Ann Arbor, Mich.*

Berichte der **Deut**schen **Keram**ischen **Ges**ellschaft. *irr.* Price varies 5 to 10M. in Germany. *Des Verbandes keramischer Gewerke in Deutschland, Berlin-Wilmersdorf, Nikolsburger Platz 1, Germany.*

Brick and **Clay Rec**ord. *bw.* $3 ($.25). *Industrial Publications, Inc., 610 Federal Street, Chicago, Ill.*

Brick and **Pottery Trade J**ournal. *m.* 6s (6d) in England. *37 and 38 Shoe Lane, London, E. C.*

British Clayworker, The. *m.* 14s (1s) in England. *43 Essex St., Strand, London, W. C. 2.*

Bureau of Mines, Bulletins, Circulars and Technical Papers, *Government Printing Office, Washington, D. C.*

Bureau of Standards, Bulletins, Circulars and Technical Papers, etc. *Government Printing Office, Washington, D. C.*

Canadian Mining Institute Bulletins. *Sec'y's. Office, Rooms 3 and 4, Windsor Hotel, Montreal, Canada.*

Céramique, La. *m.* F35. *J. León Lefévre, 123 Rue de Rennes, Paris, France.*

Chemical & Metallurgical Engineering. *w.* $5 ($.25), $6 in special zones. *McGraw-Hill Co., Inc., 10th Ave., at 36th St., New York City.*

Chimie et industrie. *m.* F50 (F10). *Société de chimie industrielle, 49 Rue de Mathurins, Paris, France.*

Diamant. *Every 10 days.* $.75 a quarter. *Alexander Duncker, Leipzig, Keilstr. 1, Germany.*

Economic Geology. *sq.* $3 ($.50). *The Economic Geology Publishing Co., 41 N. Queen St., Lancaster, Pa.*

Engineering and Mining Journal. *w.* $5 ($.25). *McGraw-Hill Publishing Co., 10th Ave., at 36th St., New York City.*

Geological Survey Publications. *U. S. Geological Survey, Government Printing Office, Wash., D. C.*

Glashütte, Die. *w.* $4. *Dresden-A-24, Germany.*

Glassworker, The. *w.* $3 ($.10). *Commoner Publishing Co., Box 555, Pittsburgh, Pa.*

Glass Industry, The. *m.* $2 ($.20). *Glass Industry Publishing Co., Inc., 19 Liberty St., New York City.*

Glass-Industrie, Die. *w.* M20 for 3 months (M2). *Industrieverlag Spaeth & Linde, Berlin, C. 2., Königstrasse 52.*

Journal of the American Chemical Society. *m.* $7.50 ($.75). *American Chemical Society, 1709 G St., Wash., D. C.*

Journal of the Chemical Society. *m.* 4/4s (7s6d). *Gurney and Jackson, 33 Paternoster Row, Lonaon, E. C. 4.*

Journal of the Franklin Institute. *m.* $6 ($.60). *The Franklin Institute, Philadelphia, Pa.*

Journal of Geology. *bm.* $4 ($.75). *University of Chicago Press, 5750–58 Ellis Avenue, Chicago, Ill.*

Journal of Industrial and Engineering Chemistry. *m.* $7.50 ($.75). *American Chemical Society, 1709 G St., Wash., D. C.*

Journal of the Japanese Ceramic Society. $4. *Sec'y. Tojiro Kurahashi, 20 Omoteche 2-chome, Akasakaku, Tokyo, Japan.*

Journal of the Optical Society of America. *6 times a year.* $5 ($1). *John P. Smith Printing Company, Rochester, N. Y.*

Journal of the Royal Society of Arts. *w.* (1s.) *G. Bell & Sons, Ltd. York House, Portugal St., London, W. C. 2.*

Journal of the Society of Chemical Industry. *bm.* 4/4s (3s6d). *Society of Chemical Industry, Central House, Finsbury Square, London, E. C. 2, England.*

Journal of the Society of Glass Technology. *q.* $8 ($2.50). *Messrs. Richard Clay & Sons, Ltd., Blackfriars House, New Bridge St., London, E. C. 4.*

Keramische Rundschau. *w.* $5 ($.10). *Keramische Rundschau, G. m. b. H. Berlin, N. W. 21.*

Mineralogical Magazine and Journal of the Mineralogical Society. *q.* £1 (5s). *Simpkin, Marshall, Hamilton Kent & Co., Ltd., 31 & 32 Paternoster Row, London, E. C. 4.*

Mining Magazine, The. *m.* $4 ($.35). *Mining Publications, Ltd., 724 Salisbury House, London, E. C. 2.*

Mining and Metallurgy. *m.* $14 ($1.50). *American Institute of Mining and Metallurgical Engineers, Inc., 212 York St., York, Pa.*

Mining and Scientific Press. *w.* $4 ($.15). *Dewey Publishing Co., 420 Market St., San Francisco, Cal.*

National Glass Budget. *w.* $3 ($.10). *Geo. F. Eibel, 426 Fourth Ave., Pittsburgh, Pa.*

New Jersey Ceramist. *q.* $2 ($.75). *J. Herdingsfeld Co., New Brunswick, N. J.*

Pottery Gazette, The. *m.* 10s (1s6d). *Scott Greenwood & Son, 8 Broadway, Ludgate, London, E. C. 4.*

Revue de L'Ingenieur et Index Technique. *m.* F60 (F6). *Bureau d'Organisation Économique (B. O. E.), 124–126 Rue de Provence.*

Revue des Materiaux de Construction, 2e partie: Briques, Tuiles, Ceramique. *m.* F32 (F3). *F. Margry, 148 Blvd. Margerita, Paris, France.*

Schnurpfeil's Review. *m.* $10. *Ingénieur H Schnurpfeil, Reichenberg (Bohemia).*

Sprechsaal: Zeitschrift für die Keramischen, Glas-und verwandten Industrien. *w.* $5 ($.10). *Müller & Schmidt, Coburg, Oberer Bürlag 16.*

Tegel. *m.* $3 ($.50). *Sveriges Tegelindustrie Färoning Kungsgaton, 66 Stockholm, Sweden.*

Tonindustrie-zeitung. *tw.* $8 ($.10). *Chemisches Laboratorium für Tonindustrie, Prof. Dr. H. Seger & E. Cramer, Berlin, N. W. 21, Germany.*

Transactions of the Ceramic Society (England). 30s. *The Ceramic Society, Stoke-on-Trent, England.*

Transactions of the Iron and Steel Institute. (London), *28 Victoria St., London, S. W., England.*

Verre, La. *m.* F35 in Belgium. *10 Rue del' Industrie, Charleroi, Belgium.*

Zeitschrift für **anorganische und allgemeine Chemie.** About 3 vols. a yr., 4 nos. a vol. $4.40 ($1.20). *Leopold Voss, Leipszig, Dörrienstrasse 16, Germany.*

Zeitschrift für **Technische Physik**—Deutschen Gesellschaft für Technische Physik E. V. *m.* $8.00. *Johann Ambrosius Barth in Leipzig.*

Information Concerning the Obtaining of Patents

The following information is published by the courtesy of *Chemical Abstracts.* The data and directions given are correct as October 1, 1921. This information will be revised and published yearly in the December number of the Journal.

Copies of any Patent can be obtained for: United States, 10 cents, sent to the Patent Office, Washington, D. C.; Austrian, M. 5, 10 or 15, according to length, sent to Lehmann & Wentzel, 1 Kärnthnerstrasse 30, Vienna; Belgian, $2.00, sent to Office des Inventions, L. Duvinage, Brussels; British, 1s. (plus postage, usually 1/2 d., outside of the kingdom), sent by Postal or Postoffice Order, payable to the Comptroller-General, to the Patent Office, 25 Southampton Buildings, London, W. C. 2; Danish, Kr. 3 for each 5 pages, sent to the Patentkommissionen, B. Niels Brocksgade 14, Copenhagen; Dutch, Fl. 1, plus postage (Fl. 0.05), sent to Octrooiraad, Juliana van Stolberglaan, The Hague; French, 1 franc, sent to L'Imprimerie Nationale, 87 rue de Vielle de Temple, Paris; German, 15 M. sent to the Reichspatentamt, Berlin; Norwegian, Kr. 1 from No. 3,125 to No. 20,935 and Kr. 0.5 from No. 20,940 on, both plus postage, sent to the Library, Styret for the industrielle Retsvern, Drammensveien 4, Christiania; Swedish, Kr. 1.00 sent to Küngl. Patent & Registreringsverket, Stockholm; Swiss, Fr. 1.20 for each ten pages of copy, or in lots of ten or more Fr. 0.80, sent to the Bureau Fédéral de la Propriété Intellectuelle, Berne; Japanese, 5 Sen, plus postage, sent to "Hatsumei Kyokwai (Invention Association), 1, Yuraku Cho Itchome, Kojimachi Ku, Tokyo. Of Canadian patents, manuscript copies only are obtainable. They are furnished by Fetherstonhaugh & Smart, 50 Queen St., Ottawa, or by the Commissioner of Patents directly. Estimates of cost may be obtained in advance. In Italy descriptions and designs of inventions are not published but one can have copies made at the office of the Ministero per l'Industria, il Commercio ed il Lavoro, Rome.

In ordering a copy of a patent, the number of the patent, the date, the name of the patentee, and the subject of the invention should be stated.

General and Miscellaneous

1. **Note on a method of determining the distribution of pore sizes in a porous material.** EDWARD W. WASHBURN. *Proc. Nat. Acad. Sci.*, 7, 115 (1921).—A granular sample of the thoroughly outgassed material is weighed and placed in a steel pressure bomb which is then evacuated until all adsorbed gases are removed. Pure mercury is then admitted to fill the bomb and a series of pressure and volume measurements are made at various pressures up to the highest pressure it is desired to employ.

The decrease in volume, ΔV accompanying a small pressure increase of Δp, in any part of the range must evidently be due to the filling of pores whose effective radii lie between the limits r and $r - \Delta r$, or

$$\frac{\Delta r}{\Delta p} = \frac{-2\gamma \cos \theta}{p^2}$$

where γ is the surface tension of the liquid and θ the angle of contact. From this relation the fraction of the total porosity due to pores having effective diameters between any two limits may be computed. E. W. W.

2. **Diatomaceous earth.** M. CHARPENTIER. *Rev. Mat. Constr. Trav. Pub.*, **141**, 109–111; **142**, 132–134; **143**, 150–152 (1921).—A general treatise on physical character, treatment, cost of working and industrial application. LOUIS NAVIAS

3. **The recovery of lubricating oil.** A. J. WILSON. *Petroleum World*, **18**, 29–30 (1921).—A résumé of the means commonly employed for treating lubricating oil which has already been passed through the engine and become too dirty to justify its further use without treatment. R. L. SIBLEY (*C. A.*)

PATENTS

4. **Transporting fuller's earth, etc.** L. G. HILT. Brit. 161,419, March 8, 1920. Fuller's earth, ground argillaceous rocks or marls, or other finely divided material or coarsely powdered or granular materials liable to produce dust are mixed with a soln. of Na_2SiO_3 or other binding agent soln. in H_2O and dried to form lumps that are dustless in transport. The powder, etc., is reformed by dissolving out the binder. (*C. A.*)

5. **Coating materials; plastic compositions; coated fabrics; joint-making packing.** J. A. LOCKE. Brit. 160,801, March 24, 1921. Coatings for Fe and smoke stacks consist of water-gas tar, menhaden oil, resinate of Mn, naptha or benzine with or without a drier, and the special pigment (without the linseed oil). An insulating paint consists of water-gas tar, menhaden oil, resinate of Mn, benzine, a drier, portland cement, asbestos, and soy-bean oil. A suitable drier consists of benzine, soy-bean oil and MnO_2. (*C. A.*)

6. **Firing ceramic ware.** ALLEGEMEINE ELEKTRIZITÄTS-GES. Brit. 150,814, March 29, 1921. In the firing of ceramic ware in tunnel ovens the heating of the high-temp. zone is interrupted at intervals to allow the goods therein to cool down to a temp. at which they are sufficiently hard to allow the trucks to be moved forward without risk of damage. The gas connections to two

adjacent tunnels may be so arranged that their high-temp. zones are fired alternately. During the interruption in firing the temp. of the preliminary heating zone of the oven is maintained or increased by auxiliary burners. Cooling devices may be fitted in the cooling zone and the heat abstracted may be used for drying. (*C. A.*)

Apparatus and Instruments

7. **A simple optical pyrometer.** H. Lux. *Elektrotechn. Z.*, **42**, 494–5 (1921); *Gas. u. Wasserfach*, **64**, 374–5.—The principle: the brightness of the filament of an incandescent lamp is adjusted by varying the resistance in the series, until it matches the brightness of the furnace, flame or other temp. source under investigation. Lux suggests a simplification of the standard Lummer-Kurlbaum pyrometer, thereby reducing the first cost appreciably. He uses an old camera and permits the image of the bright spot together with that of the filament to be focused on the ground glass of the camera. A milliammeter and a slide resistance complete the outfit. Full details are given. Operating range, 600° to 2100°. C. G. F. (*C. A.*)

8. **The present state of pyrometry.** H. Weiss. *J. phys. radium*, **2**, 33–52 (1921).—A general review. W. P. White (*C. A.*)

9. **Laboratory blue burner (Franke Model).** Hermann Zeller. *Chem. Ztg.*, **45**, 386 (1921).—It is claimed that higher temps. than the ordinary Bunsen gives can be reached with half the gas consumption, and that with an equal gas consumption temp. of 1450–1850° can be reached. The top grid to prevent striking back is made of porcelain and can not burn out.
J. H. Moore (*C. A.*)

10. **British pyrometry practice.** Ernest J. Davis. *Foundry*, **49**, 463–7 (1921).—A review. E. H. (*C. A.*)

11. **Thermoelements of non-precious metals for high temperature measurement.** F. Hoffman and A. Schulze. *Elektrotechn. Z.*, **41**, 427–33 (1920).—The usefulness at high temps. of a number of thermoelements made from wire or tubing was investigated. The Ni-Ni-alloy couples and the carbon-nickel-steel couples could be used at 1000–1200°C for 100 hrs. or more with only a little oxidation and without varying in E. M. F. more than equivalent to 10°C. The temp. is noted at which each couple can be used continuously without marked deterioration. Tables are given of the E. M. F. of the couples and the chem. compn. of most of them are included. Graphs of the E. M. F. of each element toward pure Pt and toward Cu are given. It was found that oxidation has very little effect upon E. M. F. of a couple as long as a continuous thread of the element remains. E. N. Bunting

Chemistry, Physics and Geology

12. **Silicon hydrides. IX. Reactions with alkali metal.** Alfred Stock and Karl Somieski. Kaiser-Wilhelm-Inst. f. Chemie, Berlin-Dahlem., *Ber.*, **54B**, 524–31 (1921); cf. *C. A.*, **14**, 2305.

13. Kaolins, clays, bauxites, etc.; changes in volume under the action of heat. A. BIGOT. *Compt. rend.*, **172**, 854–7 (1921).—Test specimens were prepd. by grinding to 200-mesh, moistening with H_2O, and pressing into briquettes in steel molds. The specimens were heated to successively higher temps. 100° apart, their lengths being measured after cooling from each temp. The results are expressed by temp.-length curves, and from them it is concluded that bauxites, kaolins, etc. begin to shrink below 1000°, and only when they contain free SiO_2 do they show expansion below this temp. Clays and kaolins expand before reaching their fusion temps. but bauxites do not. Mixts. of kaolin and SiO_2 show very marked swelling before fusion. This property is utilized in prepg. *artificial pumice stone* by rapidly heating schist and porcelain to their swelling temps. J. S. LAIRD (*C. A.*)

14. The flocculation of soils. N. M. COMBER. *J. Agr. Sci.*, **10**, 425–36 (1920).—This is an attempt to correlate the flocculation of soil particles with the established facts of colloid chemistry. Account is taken of the two following important causes of complication bearing upon the action of electrolytes on the soil. First "the soil particles are 'protected' by org. and inorg. colloids; second, the soil is a system of particles of all sizes." Hence a comparison of flocculation in the soil with coagulation in a simple suspensoid soil is impossible. Further light upon this subject was expected from a study of the effect of alkalinity on flocculation. Very minute details of the expts. on 8 soils are given. A lengthy discussion of the results and the following summary conclude the articles: "'Silt' like most insol. substances, when suspended in H_2O is most easily flocculated by Ca salts when the suspension is neutral. The addition of alkali stabilizes the suspension and renders flocculation more difficult. Soil 'clay,' however, behaves in an opposite manner; it pptd. from alk. suspensions more readily than from neutral suspensions. In this behavior clay resembles silicic acid and some other members of the so-called 'emulsoid' colloids. It is suggested that the clay particles are protected by such colloids and thus behave as an 'emulsoid' and not as a 'suspensoid.' If this is true, then the action of CaO, which being alkaline nevertheless flocculates clay, is seen to be in accordance with the facts of colloid chemistry. The view is advanced, and some experimental support of it is described, that clay, as an 'emulsoid,' protects the larger particles which by themselves are 'suspensoid.' The soil aggregates are conceived as having large nuclei surrounded by particles which become smaller from the center of the aggregate outwards, the clay ultimately imposing its 'emulsoid' nature on the whole aggregate, and on the whole soil in normal cases. Fine silt soils are not flocculated by $Ca(OH)_2$ on account of the inefficiency of the relatively small amt. of 'emulsoid' clay to protect the large 'suspensoid' surface exposed by the fine silt." R. B. DEEMER (*C. A.*)

15. Measurement of electrical conductivity in metals and alloys at high temperature. J. L. HAUGHTON. *Trans. Faraday Soc.*, June, 1920 (advance proof); cf. *C. A.*, **14**, 3060.—An app. for the measurement of elec. cond. at high temps., up to 1000°, is described. The principle on which the app. works

is the measurement of the voltage drop along a fixed length of the specimen, through which a constant current is passing. This voltage drop is proportional to the resistance between the points of contact so long as the current is kept const. (*C. A.*)

16. **Measurement of high degrees of hardness.** J. Innes. *J. Inst. Mech. Eng.*, **1920**, 915–32.—The hardness (H) of a material depends on the elastic properties, and the following formula is given as a means of detg. and measuring it:

$$H = (\pi^3/96).[(3 + 4N)^2(3 + N)]/N^3.(Q^3/C^2)$$

where N is the ratio of modulus of change of size to modulus of change of shape, C the modulus of change of shape, and Q the limiting shear stress. These three factors can readily be detd. separately, and if test pieces of moderate size (rods of 0.1 in. diam. and 3 in. long) are available, two of those constants, C and N, may be measured with almost any desired degree of accuracy. Q is more difficult to measure, especially with brittle materials. (*C. A.*)

17. **Mechanical properties of plastic substances (steel, glass). Importance of reactivity.** H. and F. LeChatelier. *Compt. rend.*, **171**, 695–9 (1920). From the results of torsion tests on glass as its temp. of annealing (540°,) and on mild steel at its temp. of forging (825°), it is shown that at a sufficiently high temp., and with small forces, plastic substances undergo successively three types of deformation: (1) An instantaneous elastic deformation which disappears immediately after the suppression of the force; (2) a subpermanent deformation, produced slowly and disappearing slowly after the suppression of the force, and having an order of magnitude comparable with that of the instantaneous deformation; (3) a viscous deformation continuing the subpermanent deformation; this is produced with a const. velocity and does not disappear after the suppression of the force. (*C. A.*)

18. **Crystallization, solidification, and devitrification.** A. Portevin. *Rev. ing. index. tech.*, **28**, 165–77 (1921).—Review of general principles. A. P.-C. (*C. A.*)

19. **The process of solidification as a problem of conduction of heat.** H. C. Burger. *Proc. Acad. Sci. Amsterdam*, **23**, 616–27 (1921).—The answer to this is given in a complicated mathematical form unsuitable for reproduction. E. D. Williamson (*C. A.*)

20. **Observations of temperature during solidification.** H. C. Burger. *Proc. Acad. Sci. Amsterdam*, **23**, 691–704 (1921); *Verslagen Akad. Wetenschappen Amsterdam*, **29**, 288–301.—Salol was chosen as a convenient substance to expt. within an initial test of the theoretical results already obtained (see preceding abstract). A very fine thermo-element passed along a diameter of the cylindrical tube in which the exp. was performed and the galvanometer deflection was registered photographically as the material crystd. A max. temp. was reached when the solid-liquid boundary reached the thermoelement, but this max. was always below the m. p. of the solid. The temp. curve agreed well with theory. E. D. Williamson (*C. A.*)

21. The globular silica representing the siliceous clay south of the Paris basin. RANDOIN. *Compt. rend.*, **172**, 1046–9 (1921).—A petrographic study.
L. W. RIGGS (*C. A.*)

22. Correlation of late glacial annual clay-bands in North America with the Swedish time scale. G. DE GEER. *Geol. För. Forh.*, **43**, 70–3 (1921).—G. has found that from 74% to 89% of the clay-bands seen in the U. S. agree with those in Sweden, extending from 720 to 1520 years before the end of the ice age.
W. SEGERBLOM (*C. A.*)

23. The mineralography of the feldspars. I. HAROLD ALLING. *J. Geology*, **29**, 193–294 (1921).—An application of the phase rule and thermo-equil. diagrams to the feldspars. The feldspars belong to a 5-component system, but for most purposes it is necessary only to consider the K, Na and Ca. The plagioclase and the hyalophane series constitute a series of solid solns. while the K-Na and K-Ca series possess only limited soly. and constitute eutectiferous systems. It is believed that both the K and Na feldspars are dimorphous, each existing in 2 isomeric forms, depending upon the temp. and viscosity of the magma. Some feldspars contain nephelite in solid soln. but this mineral can not be regarded as isomorphous with the normal feldspars. Some adularias and microclines show microclinic twinning in thin sections but not in thin plates, which suggests that the operation of grinding possibly caused the inversion of the metastable Na orthoclase to Na microcline. Many-zoned plagioclase feldspars are to be explained by the process of normal crystn. under rapid chill instead of magmatic corrosion, while others are the result of complex processes in which the phenomenon of undercooling plays an important rôle. The application of the physical-chem. principles to the feldspar system may also furnish a means of solving such practical geological problems as the location of a fault or the origin of amphibolites.
W. F. HUNT (C. *A.*)

PATENTS

24. Alumina, etc. H. G. WILDMAN. Brit. 161,310, Jan. 14, 1920. Clay is boiled with an alk. soln. preferably prepd. by treating a soln. of soda ash with a quantity of CaO insufficient to convert all the carbonate to hydroxide, and the clear liquor, after settling, is drawn off. The treated clay is mixed with H_2O, and SO_2 is forced into the resulting suspension until no more is absorbed. The pptd. SiO_2 is filtered off, and the soln. run into a vacuum pan fitted with closed steam coils. On heating, the Al sulfite is pptd., and the SO_2 that is evolved at the same time is stored for further use. The Al sulfite is removed, washed and ignited to Al_2O_3. The SO_2 evolved is recovered. If a trace of S remains after the ignition it may be washed out with dil. NaOH. The Na_2SO_3 soln. remaining after the Al sulfite is filtered off, if treated with CaO, yields NaOH soln. ready for treating fresh clay, and the pptd. $CaSO_3$ on ignition regenerates SO_2. When Fe is present, the clay is heated before it is treated with alkali so that it does not go into soln. with the Al. Cf. *C. A.* **14**, 603. (*C. A.*)

BOOK

25. **Factory Chemistry.** HAWKES, WM. H. New York: Longmans,. Green and Co. 59 pp. $1.00 net. For review see *Am. J. Sci.*, **2,** 53 (1921).

Refractories and Furnaces

26. **Experimental separation of lime in dolomite.** R. T. STULL. U. S. Bur. of Mines. *J. Frank. Inst.*, **190,** 739 (1920); cf. *This J.*, **4,** 558 (1921).

27. **The fundamentals of heat losses in metallurgical furnaces.** P. ROSIN. *Metal. u. Erz*, **18,** 37–45, 78–88, 99–104 (1921).—A detailed mathematical consideration of heat losses with tables of *heat conductivities of refractories.*
R. S. DEAN (*C. A.*)

28. **Selection of Fuel for Industrial Heating.** ANON. *Chem. Met. Eng.*, **25,** 116–118.

CHARACTERISTICS OF VARIOUS INDUSTRIAL GASES

	B.t.u. per cu. ft.	Vol. of air for combustion	**Max. temp., °F	**Max. temp. with 100% excess air	B.t.u. per cu. ft. of foregoing mixture
Acetylene	1470	12	4200	2600	59
Natural	960	9.8	3300	2100	47
Coal or city	600	5.7	3500	2200	48
Coke oven	550	5.3	3400	2200	48
Carbureted water	580	5.2	3600	2300	50
Oil producer	450	4.9	3300	2100	47 (42)†
*Fuel	380	3.4	3500	2300	49
Water	300	2.4	3600	2400	50 (52)†
Producer	130	1.8	2800	2000	41 (28)†
Blast furnace	100	1.3	2500	1900	41 (28)†

*Gasification by continuous process using hot coke for water gas.

**With cold gas and air.

† Calculated by abstractor from values given in columns 1 and 2. H. F. S.

29. **Theoretical considerations on the subject of the composition of the gases of combustion and the gasification of coal.** J. SEIGLE. *Rev. metal.*, **18,** 81–91 (1921).—Stoichiometric calcns. on the compn. of the gaseous products of combustion. The formula is developed, $^{100}/Aa + 0.5d + 1.5e + f = 100$, where $A = \%$ N_2 in the dry entering gas, $a = \%$ N_2 in the moist gaseous product, $d = \%$ CO in the moist gaseous produce, $e = \%$ H_2 in the moist gaseous product and $f = \%$ water vapor in the product. Examples are given showing the application of this formula to (1) complete combustion by dry gas, (2) gasification by air more or less charged with O_2 or CO_2, and water vapor. Similar calcns. are made for *blast furnaces and for elec. furnaces.*
E. H. DARBY (*C. A.*)

30. **The use of pulverized coal under stationary boilers.** ED. LIÉVENIE. *Age de fer.*, **37,** 833–6 (1921).—Notes on the machinery and equipment re-

quired, the early troubles encountered in its application, the advantages of the system, and the method of operation. A. P. C. (*C. A.*)

See also No. 15.

Glass

31. Dispersion in optical glasses. F. E. Wright. *J. Optical Soc. Am.*, **4**, 148–59 (1920); *Science Abstracts*, **23A**, 500; cf. *C. A.*, **14**, 3135.—A somewhat more extended treatment of the same subject is contained in a paper by the same author published in *This J.*, **3**, 783 (1920).

32. Glass manufacture; enamels; glazes. A. A. Kelly and B. D. Jones. Brit. 160,495, Nov. 20, 1919. In the manuf. of glass, vitreous enamels, and glazes, Na pentaborate is substituted for borax or boric acid, and the necessary adjustment of the alkali content is made in any suitable manner. (*C. A.*)

GLASS

33. Adressbuch der Glasindustrie in Deutschland. Verlag von Müller und Schmidt. Coburg. M43.

See also No. 17.

Enamels

34. The use of enameled bombs in calorimetry. C. Matignon and (Mlle.) G. Marchal. *Compt. rend.*, **172**, 921–22 (1921).—The HNO_3 produced in the explosion attacks the enamel and is neutralized by it. The loss of acid may lead to an error of $^1/_2$%. It is rendered negligible by first treating the enamel for some hours with dil. acid. W. P. White (*C. A.*)

Cement, Lime and Plaster

35. Analysis of portland cement. Fabio Ferrari. *Giorn. chim. ind. applicata*, **2**, 434–7 (1920).—F. applies the following methods to the analysis of portland cements in order to secure great rapidity of execution without sacrifice of exactness. Coarsely powder the clinker in a steel mortar of the Abich type, then grind in an agate mortar to pass through 3600 mesh per sq. cm. Dry the substance in the air, and weigh out 3 samples, (1) for detn. of H_2O, (2) for detn. of loss on calcination, silicic, Al_2O_3, CaO and MgO, (3) for detn. of insol. silicic residue, Fe_2O_3 and SO_3. *Moisture.*—Weigh 1 g. substance in a large Pt crucible, heat for 1 hr. at 120°, cool in a desiccator and weigh. *Loss on calcination.*—Use an elongated crucible of 60 cc. capacity. Heat 1 g. substance in an elec. furnace for 30 min. at not less than 950°. *Total SiO_2.*—Treat the residue from the above calcination with 4 g. HNO_3 (d. 1.52), drop by drop, allowing it to run down the walls of the crucible. Keep the crucible covered as much as possible with a watch glass. On addition of HNO_3 and until the whole residue is moistened, stir the substance about with a glass rod. Place the covered crucible containing the now gelatinous mass in an oven at 100° for 15 min. Stir the substance about from time to time with the rod. Then add 30 cc. boiling H_2O acidulated with HNO_3. Keep the mixt. at incipient boiling for 8–10 min., then filter. Wash the residue with boiling H_2O. Keep

until the washings are no longer acid, using as little H_2O as possible. Dry the residue over the pump, ignite for 30 min. in the elec. furnace, and weigh. *Al_2O_3 + Fe_2O_3*.—To filtrate from the above SiO_2 detn. add 10 cc. 10% NH_4NO_3 soln., heat to ebullition, and ppt. with slight excess of NH_4OH free of CO_2. Allow the ppt. to deposit, filter, wash twice with boiling H_2O. Dissolve the ppt. by dropping upon it warm dil. HNO_3, repeat the pptn. with the NH_4OH, filter and wash the ppt. completely with warm H_2O containing 1% NH_4NO_3, dry over the pump, ignite and weigh. *CaO*.—Take the combined filtrates from the pptn. of the mixed oxides above, concentrate to 150 cc., heat to ebullition, and ppt. with an excess of concd. boiling soln. of NH_4 oxalate. Keep at rest for 2 hrs. at about 80°. Filter, wash carefully with warm 1% NH_4OH oxalate soln., burn while moist and ignite with gradual increase of temp. for 30 min. over the blast. Weigh the residue as CaO. *MgO*.—To the filtrate from the CaO pptn. rendered acid by HNO_3, add Na_2HPO_4 in excess, bring to boiling and ppt. with 80–90 cc. 10% NH_4OH. Allow the ppt. to deposit. After the lapse of an hr., filter through a crucible of the Gooch-Neubauer type, wash with $2^1/_2$% NH_4OH, dry and calcine in the elec. furnace, and weigh as $Mg_2P_2O_7$. (In absence of such a crucible, collect the ppt. on a filter, wash completely with $2^1/_2$% NH_4OH, dry, transfer as much as possible of the ppt. to a weighed Pt crucible, burn the filter in a Pt spiral, transfer the ash to the same crucible. Heat at first with small flame until no more NH_3 is given off, increase the heat slowly, until the ppt. is white. Weigh.) *Insol. SiO_2* (Siliceous residue).—Ignite 2 g. of the substance for 15–20 min., transfer to a procelain dish, and treat as above for total SiO_2, but using 1.19 HCl in place of HNO_3. (The substitution of HCl for HNO_3 is to facilitate detn. of Fe_2O_3 in the filtrate as described below.) Transfer the washed residue to a porcelain dish by means of boiling 3% Na_2CO_3 soln. Heat with 150 cc. of this soln. at near 100° for 20 min. Filter, wash the residue thoroughly, first with Na_2CO_3 soln., then H_2O. *Fe_2O_3*.—Take half of the HCl filtrate from the above detn. of insol. SiO_2. Add 10 cc. concd. HCl, bring to 200 cc., oxidize the Fe completely with Cl water. Cool, agitate, and add drop by drop, a cold clear 6% soln. of NH_4 nitrosophenylhydroxylamine. (*A*) (Prepn. of *A*: Place 1 l. H_2O in a large vessel, add 60 g. $PhNO_2$ and 30 g. NH_4Cl. Agitate to form an emulsion, and then while still agitating, add slowly, 1 g. at a time, 70–75 g. pure Zn in fine powder. Keep the temp. between 16–18° by addition of small pieces of ice. Reduction is complete when the odor of the $PhNO_2$ disappears. Filter on the pump, wash the $Zn(OH)_2$ with a little H_2O. Cool the filtrate to satn., when an abundant ppt. of PhNHOH forms. Dry this over the pump then for an hr. between filter paper. Dissolve in 400–500 cc. Et_2O, filter through dry folder filter. Cool the clear soln. to 0°, pass dry NH_3 through it for 10 min., then an excess (about 1 vol.) of fresh amyl nitrate. *A* forms at once as shining, snow-white crystals. Dry, wash with Et_2O, crush between filter paper, and preserve in a hermetically closed bottle in presence of $(NH_4)_2CO_3$. The product is easily sol. in H_2O, the aq. soln. remaining unaltered for weeks. The soln. should always be filtered before

using.) The characteristic brick-red ferric salt forms at once as ppt., pulverulent at first then uniting into easily friable large cryst. masses. Continue agitation, adding at least 1/5 excess of the reagent (0.0833 g. *A* are necessary for 0.01 g. Fe), when the base itself will ppt. as a voluminous white, soft, pulverulent microcryst. powder. Allow the whole to stand 15–20 min., break up the mass with a glass rod, filter and dry the ppt. over the pump with moderate aspiration. Wash twice with cold H_2O acidulated with HCl, then with H_2O alone until the washings are no longer acid. Wash repeatedly with NH_4OH, and again a few times with H_2O alone. Dry completely, bring to redness in a closed Pt crucible, then ignite in the air. Weigh as Fe_2O_3. *SO_3*.—Take the other half of the HCl filtrate from detn. of insol. SiO_2, bring to 250 cc., heat, and ppt. with NH_4OH and $(NH_4)_2CO_3$ in excess. Allow the ppt. to settle, filter and wash. Add a drop of methal orange to the filtrate, neutralize with HCl, then add 1 cc. HCl (d. 1.17), and bring to boiling. While agitating, add 50 cc. boiling 2% $BaCl_2$ soln. Allow to stand 1 hr. at 90°, filter, wash, dry a little, ignite moist in Pt. crucible, weigh as $BaSO_4$. The above methods may be applied to the analysis of *limestones*, crude powders and *shales*. These should previously be weighed and then scorified at about 1400° (the shales first mixed with a known wt. of very pure $CaCO_3$) for 30–40 min. Weigh again, powder in an agate mortar, heat, and keep in desiccator, and make the analysis on an aliquot part. ROBERT S. POSMONTIER (*C. A.*)

36. Chemical analyses of cement as indicators of behavior. R. J. COLONY. *Eng. News-Record*, **86**, 736 (1921).—A résumé of a paper read before the Am. Inst. of Mining and Met. Engineers. C. recommends that the results of chem. analyses of cement be calcd. to show actual components of the cements and that the values thus obtained be used as a basis for judging the quality. C. also recommends a limiting value for the ratio between the CaO, and the sum of the SiO_2, Al_2O_3, and Fe_2O_3. J. C. WITT (*C. A.*)

37. Lime and cement industries in Algeria and Morocco. E. DARGERY. *Rev. Mat. Constr. Trav. Pub.*, **144**, 170–71 (1921).—A plea for the consolidation of the lime and cement industries in Algeria and Morocco for their own betterment and for the eliminating of foreign capital. Some import and export figures are given for 1919 and 1920. LOUIS NAVIAS

38. Law for hardening of cements. J. BIED AND E. GARNIER. *Rev. Mat. Constr. Trav. Pub.*, **144**, 168–170 (1921).—It has been found that the resistance to compression of a plastic mortar at 84 days can be calcd. from the compression data at 7 and 28 days. Over 800 tests for 1/3 plastic mortar have borne this out. The equation is $R_{84} = K(2R_{28} - R_7)$, where R is resistance for the no. of days indicated, and K is a constant, being 1 for cements, and 1.25 for limes. This equation may be put in the form $\frac{y = at,}{t + b}$ being that of an equilateral hyperbola. For cements ($K = 1$) it may be reduced to $\frac{y = 5\,at}{28 + 5t}$ and for limes ($K = 1.25$), to $\frac{y = at}{t - 0.24}$, where $t =$ time in weeks and $y =$ corresponding resistance. The depth to which a sinker will fall in a

cement has been combined in an equation with the time. For cements $(t - 3.6)(h - 2.7) = 152$ and for limes $(t - 8.5)(h - 8.7) = 429$, where t = time in hours since the mixing of the mortar and h = depth in tenths mm. These equations have been tested, and express the exp. results. LOUIS NAVIAS

39. **Slag brick.** ANON. *Rev. Mat. Constr. Trav. Pub.*, **143**, 148–150 (1921).—Slag of composition SiO_2, 40.6%; CaO, 11.2%; Al_2O_3, 18.5%; Fe_2O_3, 22.8%; and MgO, MnO_2 and alkalies, 6.9%, is mixed with slaked lime, *e. g.:* 85–88% slag and 12–15% lime, and ground between stone mullers. Then 6–10% quicklime and 10–15% water are added, mixed and allowed to stand 12–36 hours. The brick are then pressed, steam dried, air dried and are ready for use. LOUIS NAVIAS

40. **Lime industry in Egypt.** A. DUPRAZ. *Rev. Mat. Constr. Trav. Pub.*, **143**, 145–146; **144**, 172 (1921).—Describes the pre-war method of calcining limestone in a primitive stone walled kiln, lined inside with crude brick, and using vegetable matter, *i. e.*, fibres, leaves, etc., for fuel. Describes the war method of utilizing unburned cinders and coals from railroads, furnaces, etc. LOUIS NAVIAS

41. **What causes cement to be quick setting?** BAILEY TREMPER. *Concrete* (Cement Mill Section), **18**, 144 (1921).—T. has observed that quick setting (or quick stiffening) cement is most likely to be produced when the temp. in the finishing mills is abnormally high. From expts. with gypsum and plaster of Paris, he believes that the effect is the result of dehydration of gypsum during the grinding process, when the temp. exceeds 110°.

J. C. WITT (*C. A.*)

42. **Theory of the setting and hardening of Portland cement.** FABIO FERRARI. *Giorn. chim. ind. applicata*, **2**, 620–4 (1920).—A consideration of the prevailing theories upon the action of Portland cement, supplemented by F.'s own expts., led to the following conclusions. The high temp. of consolidation of Portland cement, the normal presence in this of di-Ca silicate and of ternary silicates of the type $SiO_2.Al_2O_3.2CaO$; $2SiO_2.Fe_2O_3.2CaO$, in which all the Fe and nearly all the Al are comprized show that free CaO must be enumerated among the ordinary components of Portland cement. The CaO (normally in solid soln. and hence slowly attackable by H_2O) can be considered as an expansive agent only if present in excess or in such a form that it can produce on hydrating, tensions superior to the opposed reaction forces of the cementitious mass that contains it. On this basis, setting, properly speaking, must be looked upon as due to the adhesion of the $Ca(OH)_2$ with the hydraulically inactive elements and with the hydraulic elements not yet attacked by the H_2O during the lapsing period of time. (Free CaO gives rise to a hydrate with greater rapidity than does any other component of the Portland cement in the act of mixing, and during the short period, varying from a few min. to some hrs., that follows.) Hardening on the same basis, must be attributed to the development of contact mutually between hydrates and between the hydrates and the inactive components. This contact is due to the mobility which the active compds. acquire, in

conformity, not only with the difference of soly. between the latter as anhydrides and as hydrates, but also because of the pressures which the free CaO, in taking on H_2O, exercises upon those hydrates, upon any anhydrous compds. and in general upon any other more or less sol. component.

ROBERT S. POSMONTIER (*C. A.*)

43. Cement colors and their chemical testing. C. R. PLATZMANN. *Farben-Ztg.*, **26**, 1894–5 (1921).—Good cement and mortar colors should be mineral pigments, contain no free acids (SO_3, Cl) and H_2O-sol. substances, and be unaffected in color by CaO, cement, light, etc. The color strength may be detd. by the usual method of rubbing up the pigment with a definite amt. of ZnO. The relative coloring strength of an Fe_2O_3 pigment is dependent on its content of Fe_2O_3, Al_2O_3, and its loss on ignition. Black cement colors are either C or Mn blacks; ultramarine is best adapted for producing the blue colors; greens usually consist of Mg Al silicates and produce only dull green colors.

F. A. WERTZ (*C. A.*)

44. Effect of coloring materials on the strength of mortar. DUFF A. ABRAMS. *Eng. News-Record*, **86**, 721 (1921).—Compression tests were made on 1–2 mortar contg. a blue coloring material, red iron oxide up to 15% (in terms of wt. of cement), and carbon black up to 10%. The blue caused a pronounced increase in strength, the red a slight decrease, and the carbon black a material decrease.

J. C. WITT (*C. A.*)

PATENTS

45. Dental cements. S. SCHIFF. Brit. 161,868, June 16, 1920. Addition to 145, 052 (*C. A.*, **14**, 3134). Colloidal silicic acid, either in the sol condition or as hydrogel, acetogel, or alcogel, is added to certain classes of dental cements to increase their hardness and transparency. The cements in question are those composed of ZnO and a soln. of $ZnCl_2$ or $ZnSO_4$ or a phosphate, and those containing silicates or polysilicates with oxides, phosphates, borates, etc. of various metals and a soln. of phosphoric acid. The colloidal silicic acid may be added either to the soln. or to the solid ingredient of the cement, or to both, or it may be used alone with metallic oxides. (*C. A.*)

46. Slaking lime. E. R. SUTCLIFFE. Brit. 160,556, Dec. 22, 1919. Lime or the like is fed by a hopper into the first of a series of parallel cylinders through which it is propelled by stirring and conveying vanes. H_2O is sprayed upon the lime in the cylinder from a pipe parallel with the axis, and this cylinder is preferably provided with a H_2O jacket. The other cylinders are provided with steam jackets preferably of semicircular form so as to enclose the upper half only. The cylinders are connected at each end by cylinders forming vertical shafts which are provided alternately with segmental plates and segmental gratings so as to allow the material to be traversed in the desired path. A suitable construction is specified. (*C. A.*)

BOOK REVIEWS

Chemical Warfare. AMOS A. FRIES (Brigadier-General, C. W. S., U. S. A., Chief of Chemical Warfare Service) and CLARENCE J. WEST (Major, C. W. S. Reserve Corps, U. S. A., Nat'l. Research Council). pp. x + 445 and 121 figs. McGraw-Hill Book Co., New York, 1921. A very readable account of the history of the development of chemical warfare and its place in modern military tactics. It is difficult to understand how any American citizen could read this book and not become a strong advocate of the development of this branch of our Army to the point where knowledge of this terrible weapon is so complete that, in time of war, the defensive and offensive branches of the Service could be rapidly and efficiently expanded to a war footing. Not even the most ardent pacifist could object to a research program directed toward the development of the most efficient methods of protection against this frightfully efficient weapon, and an equal measure of preparedness to retaliate in kind will meet the approval of all advocates of a strong policy of national defense. A dollar spent in chemical warfare preparedness should produce more "pounds of preparedness" than could be secured by spending it on any other branch of the army; that is, chemical warfare preparedness, in peace time, is comparatively inexpensive.

The ceramic readers of this book will note with interest the adoption of the tunnel kiln for the activation of charcoal, and while the special field of the ceramic chemist does not touch very closely the problems of chemical warfare, there are some manufacturing problems where high temperatures and special ceramic bodies will find application. E. W. W.

American Society of Testing Materials: Standards. Issued triennially, 1921 Ed. pp. 890. Cloth $10; half-leather, $11.50. A. S. T. M., 1315 Spruce St., Philadelphia, Pa. This volume contains 160 methods of testing engineering materials. These methods, all of which have received the official approval of the Society, are distributed among the various materials as follows: 61 relating to steel and wrought iron; 7 to pig and cast iron and finished castings; 31 to non-ferrous metals; 18 to cement, lime, gypsum and clay products; 10 to preservative coatings and lubricants; 19 to road materials; 4 to coal and coke; 6 to timber and timber preservatives; 2 to rubber and 2 to miscellaneous subjects. Those of most interest to the ceramic industries cover: standard specifications for drain tile, paving brick, portland cement, natural cement, clay, sewer pipe, cement-concrete sewer pipe, building brick, gypsum plasters; standard definitions of terms relating to sewer pipe and clay refractories; standard specifications for making the following tests: (*a*) chemical analysis and physical and chemical properties of portland cement, (*b*) load test of refractory materials at high temperature, (*c*) chemical analysis of refractory materials including chrome ores and chrome brick, (*d*) fire tests of material in construction, (*e*) measurement of porosity and permanent volume changes in refractory materials, (*f*) softening point tests on fire-clay brick, (*g*) determination of unit weight of aggregate for concrete; standard specifications for making and storing concrete specimens in the field;

recommended practice for laying sewer pipe; standard methods for mechanical analysis of sand and other fine materials; a variety of testing methods for road building materials.

Many, if not most of the methods described are the result of a gradual development based upon the practical experience of many engineers. Although approved by the Society in their present form, it is, of course, to be expected that many of these methods will undergo further changes and improvements as time goes on. Sources of error will be discovered and eliminated, methods will be simplified or refined according to the necessities of the case, and certain incongruities now present will be eliminated. It is to be hoped that the adoption of a method by the Society on the basis of the best engineering experience will eventually in all cases, be followed (if it cannot be preceded) by a thorough scientific examination of the method by some institution properly staffed and equipped for such work. The critical study of proposed testing methods is a task for the physicist and the chemist. The selection of a method for a given purpose, after the results of such a critical study are available, belongs to the province of the engineer. E. W. W.

Correction

57. The new Meurer enamel spraying process. ANON. *Sprechsaal,* **54,** 490–91 (1921), *This J.*, Vol. 4, No. 9, page 787, should read *Sprechsaal,* **45,** 139–140 (1921).

ACTIVITIES OF THE SOCIETY

Recent Actions of the Board of Trustees

November 10, 1921. It was voted that the American Ceramic Society should join the American Society for Testing Materials by payment of the dues of fifteen dollars.

It was voted that the Secretary should promote publicity by (*a*) the use of reprints, (*b*) addresses, and (*c*) press notices.

It was voted to consider the appointment of Miss Norah Binns as Assistant Secretary for the year 1922, provided she can be secured at a salary which will meet with the approval of the Board.

It was voted to authorize the Secretary to promote the establishment of Ceramic Trade Schools.

It was voted to recommend that provision be made for a standing "Service" Committee on Ceramic Education, the chairman to be a member of the Coördinating Service Council.

It was voted that the Society should have a booth and a "Day" at the Exposition of Chemical Industries.

It was voted to have an illustrative exhibit at the Exposition.

It was voted to instruct Secretary Binns to negotiate for the English and European excursion next summer, in the interests of the entire Society.

It was voted to provide stenographic service for the Divisional meetings at the annual meeting.

It was voted to encourage exhibits at the annual meeting.

Recent Action of the Society

November 16, 1921. One hundred thirty-one votes were cast on the Proposed Amendments to the Constitution and By-Laws; one hundred twenty-eight affirmative, three negative. The amendments are carried and go into immediate effect. The articles and sections as amended are here given in full.

CONSTITUTION

Article VI

Standing Committees

(1) The following Standing Committees shall be appointed annually by the board of Trustees:

1. Rules
2. Publications

3. Membership
4. Standards
5. Sections and Divisions
6. Papers and Programs
7. Research
8. Geological Surveys
9. Data
10. A Coördinating Service Council.

The chairman of each committee shall be appointed by the Board of Trustees.

(2) The Committee on Rules shall consist of five members in addition to the chairmen of the Rules Committees of the divisions having such committees. It shall receive all recommendations relating to changes of Constitution and By-Laws and shall report upon the same to the Secretary for transmission to the Society. It shall have power to propose changes in the Rules of the Society.

(3) The Committee on Publications shall consist of the Editor and four members. The duties of the Editor and Committee on Publications are defined under Article X on Publications.

(4) The Committee on Membership shall consist of at least five members in addition to the chairmen of Membership Committees of the divisions having such committees, and shall have power to appoint sub-committees. Its function shall be to undertake systematically the enlargement of the membership of the Society amongst those interested in the ceramic and allied industries.

(5) The Committee on Standards shall consist of a chairman appointed by the Board of Trustees and topic groups as follows:

Group on Definitions, consisting of three members appointed by the Board of Trustees.

Group on Raw Material Specifications, consisting of three members appointed by the Board of Trustees.

Group on Standardization of Test, consisting of one member elected by each Division.

Group on Standardization of Products, consisting of one member elected by each Division.

(6) The divisional Standardization Committees shall be appointed in and by their respective divisions. Their functions shall be the preparation of test and specifications for the materials and products of their respective branches of ceramic industry. Each shall be responsible to its own division, but all reports, resolutions or recommendations that are to be printed or generally distributed shall be approved by the Committee on Standards before publication.

(7) The function of the Committee on Standards shall be to prepare or have prepared tests and specifications for ceramic materials and products and to submit to the Board of Trustees written reports, resolutions and recommendations relating thereto. The Committee may report at any regular

meeting of the Society. For adoption, these reports, resolutions, and recommendations must be submitted in printed form to the members of the Society at least six months before a vote may be taken, during which time any amendments, changes, or corrections, suggested by any member may, with the approval of the Committee, be incorporated. The reports, resolutions, and recommendations as amended shall then be submitted by letter ballot to the voting members. A two-thirds vote shall be required for adoption, and the polls shall close 60 days after distribution of the ballot.

(8) The Committee on Sections and Divisions shall consist of five members in addition to the chairmen of the Divisions. Its duties shall be to promote the organization and welfare of Local Sections, Student Branches, and Divisions.

(9) The Committee on Papers and Programs shall consist of the secretaries of the Divisions, the Secretary of the Society, and such other persons as the Board of Trustees may deem advisable. Its duties shall be to procure papers and discussions for the meetings and publications of the Society. The Committee may require an abstract of any paper submitted before placing it upon a program.

(10) The Committee on Research shall consist of a chairman and three members appointed by the Board of Trustees, and one member elected by each Division. Its duties shall be to organize and encourage scientific investigations pertaining to the ceramic and related industries, especially those investigations which will stimulate the development of our national industries and resources. It shall be empowered to coöperate with similar committees of other scientific societies and with Government bureaus.

(11) The committee on Geological Surveys will coöperate with National and State Geological Surveys and Associations in planning laboratory and plant investigations instituted by them, and interpreting data. This committee shall consist of a chairman and four members appointed by the Board of Trustees.

(12) The Committee on Data shall arrange symposiums and prepare for publication monographs, bibliographies, statistics, etc. This committee shall consist of a chairman appointed by the Board of Trustees and one member elected by each Division.

(13) The Coördinating Service Council shall consist of the General Secretary, ex-officio chairman, and the chairmen of the Committees on research, Standards, Geological Surveys, and Data. The Council shall have general supervision of the work of these committees, for the purpose of coördinating their work within the Society and with the work of other organizations on ceramic topics and problems.

BY-LAWS

Section VIII

(1) The Board of Trustees shall appoint such special committees as may seem necessary for the proper conduct of the affairs of the Society.

(2) All Special Coöperative Committees shall be appointed only on nomination of the Coördinating Service Council.

Section IX

The Board of Trustees shall have power to make any rules not inconsistent with the constitution and By-Laws for the conduct of its business.

COÖRDINATING SERVICE COUNCIL

General Secretary, ex-officio Chairman
Four members, appointed by Board of Trustees to serve as Chairmen of Committees 1 to 4, inclusive

		Committee Members	Coöperation with other organizations
1. Committee on Research	Pure Science Applied and Industrial Science	3 members appointed by Board 1 member chosen by each Division	National Research Council (Div. Chemistry and Chemical Technology, Div. Research Extension, and Div. Engineering) Federal Bureaus Semi-Public, Commercial, and Industrial Laboratories Universities Trade and Technical Associations
2. Committee on Standards	(*a*) Definitions (*b*) Raw Materials Specifications (*c*) Standardization of Tests (*d*) Standardization of Products	(*a*) 3 members appointed by Board (*b*) 3 members appointed by Board (*c*) 1 member chosen by each Division (*d*) 1 member chosen by each Division	American Society for Testing Materials (Committees C-1 to C-11, inclusive, D-4, and D-9) Foreign Ceramic Societies Trade and Technical Associations Federal Bureaus American Engineering Standards Committee, etc.
3. Committee on Geological Surveys	Advisory on Tests and Interpretation of Data	4 members appointed by Board	National Research Council (Div. Geology and Geography) U. S. and State Geological Surveys
4. Committee on Data	(*a*) Symposiums (*b*) Monographs (*c*) Bibliographies (*d*) Statistics	1 member chosen by each Division	National Research Council Trade and Technical Associations Federal Bureaus Commercial Laboratories Universities

New Members Received during November, 1921

Resident Associate

Baker, Earl B., 22 Sixteenth Ave., Columbus, Ohio, U. S. Bureau of Mines.
Crow, Waller, 2828 Smallman St., Pittsburgh, Pa., Secretary-Treasurer, Schaffner Engineering and Equipment Co.

Funkhouser, E. N., Hagerstown, Md., Secretary, Maryland Glass Sand Co.
Hartmann, Miner L., 3006 McKoon Ave., Niagara Falls, N. Y., Director, Research Laboratory, The Carborundum Co.
Keese, A. W., 1312 E. 112th St., Cleveland, Ohio, General Superintendent, Collinwood Shale Brick and Supply Co.
Lee, P. William, 395 Fourteenth Ave., Columbus, Ohio.
Richeux, William A., 343–347 Cortlandt St., Belleville, N. J., General Manager, "Isolantite."
Wilson, Della F., 612 Howard Place, Madison, Wis., Instructor, University of Wisconsin.
Zahm, Robert Charles, 272 East 11th Ave., Columbus, Ohio, U. S. Bureau of Mines.

Foreign Associate

Endell, Kurd, Berlin Steglitz, Breitestr. 3, Germany.

Corporation

Clinchfield Products Corporation, 350 Madison Ave., New York City.
Proctor & Schwartz, Inc., Seventh St. and Tabor Rd., Philadelphia, Pa.

Report of the Nominating Committee for 1922-23

TO THE VOTING MEMBERS OF THE AMERICAN CERAMIC SOCIETY:

The Nominating Committee makes the following report on nominations for officers for the year 1922–1923:

President—F. H. Riddle,
Champion Porcelain Co., Detroit, Mich.

Vice President—E. W. Tillotson,
Mellon Institute, Pittsburgh, Pa.

Treasurer—R. K. Hursh,
University of Illinois, Urbana, Ill.

Trustee—B. E. Salisbury,
Onondaga Pottery, Syracuse, N. Y

AUTHOR INDEX

The references are to page numbers. The capital letters in parentheses have the following significance: (A) Abstract, (B) Book, (O) Original paper, (P) Patent.

A

B

C

H

I

J

K

M

T

SUBJECT INDEX

The references are to page numbers. The capital letters in parentheses after the titles have the following significance; (A) Abstract, (E) Editorial, (O) Original, (P) Patent.

F

Q

American Ceramic Society

Year Book
1920 - 1921

2ª

R. H. MINTON

PRESIDENT, 1920-1921

OFFICERS, 1920--1921

President

R. H. Minton ....Metuchen, New Jersey

Vice-President

E. T. Montgomery ....Franklin, Ohio

Secretary

Charles F. Binns ....Alfred, New York

Treasurer

R. K. Hursh ....Urbana, Illinois

Trustees

R. D. Landrum, term expires 1921
M. F. Beecher, term expires 1922
F. H. Riddle, term expires 1923
H. F. Staley, Past President
R. T. Stull, Past President

EX-PRESIDENTS AND WHERE MEETINGS HAVE BEEN HELD

Herbert A. Wheeler	1899—1900	Columbus, Ohio
Karl Langenbeck	1900—1901	Detroit, Mich.
Charles F. Binns	1901—1902	Old Point Comfort, Va.
Ernest Mayer	1902—1903	Cleveland, Ohio
Edward C. Stover	1903—1904	Boston, Mass.
Francis W. Walker	1904—1905	Cincinnati, Ohio
William D. Gates	1905—1906	Birmingham, Ala.
Willard D. Richardson	1906—1907	Philadelphia, Pa.
Stanley G. Burt	1907—1908	St. Louis, Mo.
Albert V. Bleininger	1908—1909	Columbus, Ohio
Ross C. Purdy	1909—1910	Pittsburgh, Pa.
H. Ries	1910—1911	Trenton, N. J.
Charles Weelans	1911—1912	Chicago, Ill.
Arthur S. Watts	1912—1913	Washington, D. C.
Ellis Lovejoy	1913—1914	Wheeling, W. Va.
Cullen W. Parmelee	1914—1915	Detroit, Mich.
Richard R. Hice	1915—1916	Cleveland, Ohio
Lawrence E. Barringer	1916—1917	New York, N. Y.
George H. Brown	1917—1918	Indianapolis, Ind.
Homer F. Staley	1918—1919	Pittsburgh, Pa.
R. T. Stull	1919—1920	Philadelphia, Pa.

OFFICERS OF INDUSTRIAL DIVISIONS, 1920--1921

Art Division

Leon V. Solon, Temporary Chairman

F. H. Rhead, Temporary Secretary

Enamels Division

E. P. Poste, Chairman — R. R. Danielson, Secretary

Glass Division

S. R. Scholes, Chairman — E. W. Tillotson, Secretary

Refractories Division

A. F. Greaves-Walker, Chairman — R. M. Howe, Secretary

Terra Cotta Division

F. B. Ortman, Chairman — R. L. Clare, Secretary

White Wares Division

C. E. Jackson, Temporary Chairman

T. H. Sant, Temporary Secretary

OFFICERS OF LOCAL SECTIONS, 1920--1921

Pittsburgh District Section

C. R. Peregrine, Chairman — C. C. Vogt, Secretary

F. W. Walker, Councilor

Northern Ohio Section

A. F. Gorton, Chairman — Charles H. Stone, Jr., Secretary

R. D. Landrum, Councilor

St. Louis Section

I. A. Krusen, Chairman — Gail R. Truman, Secretary

C. W. Berry, Councilor

New England Section

C. J. Hudson, Chairman — M. C. Booze, Secretary

M. F. Beecher, Councilor

Central Ohio Section

M. B. Cheney, Chairman — J. D. Whitmer, Secretary

A. S. Watts, Councilor

Chicago Section

H. T. Bellamy, Chairman — F. L. Steinhoff, Secretary

C. W. Parmelee, Councilor

New York State Section

S. C. Linbarger, Chairman — J. B. Shaw, Secretary

L. E. Barringer, Councilor

Eastern Section

Abel Hansen, Chairman — G. H. Brown, Secretary

C. A. Bloomfield, Councilor

STANDING COMMITTEES, 1920--1921

Committee on Co-operation

E. W. Washburn, Chairman
S. G. Burt
F. B. Dunn
W. E. Emley
H. E. Maddock
T. Poole Maynard
G. A. Rankin
J. W. Sanders
F. L. Steinhoff
D. F. Stevens
F. W. Walker, Jr.

Committee on Membership

F. H. Riddle, Chairman
L. J. Frost
H. K. Kimble
A. A. Klein
S. C. Linbarger
Atholl McBean
F. H. Rhead
T. H. Sant
S. R. Scholes
Frederick Stanger
August Staudt
D. F. Stevens
Gail R. Truman
J. D. Whitmer

Committee on Papers and Programs

R. H. Minton, Chairman
Chas. F. Binns
M. C. Booze
G. H. Brown
A. F. Greaves-Walker
F. B. Ortman
E. P. Poste
S. R. Scholes
J. B. Shaw
F. L. Steinhoff
C. H. Stone, Jr.
Gail R. Truman
C. C. Vogt
J. D. Whitmer

Committee on Publications

L. E. Barringer, Chairman
A. V. Bleininger
H. Ries
H. F. Staley
E. W. Tillotson

Committee on Research and Development

G. H. Brown, Chairman
P. H. Bates
A. V. Bleininger
W. M. Clark
R. M. Howe
J. S. Laird
R. B. Sosman
R. T. Stull
E. W. Washburn
A. S. Watts

Committee on Rules

A. S. Watts, Chairman
R. L. Clare
R. K. Hursh
T. A. Klinefelter
J. B. Shaw

Committee on Sections and Divisions

S. C. Linbarger, Chairman
C. C. Ashbaugh
Leslie Brown
F. A. Kirkpatrick
R. D. Landrum
A. T. Malm
G. D. Morris
F. B. Ortman
C. W. Parmelee
E. P. Poste
E. W. Tillotson

Committee on Standards

M. F. Beecher, Chairman
C. W. Berry
M. C. Booze
E. E. F. Creighton
R. R. Danielson
E. C. Hill
R. M. Howe
R. K. Hursh
F. H. Riddle
J. B. Shaw
O. J. Whittemore
Hewitt Wilson

SPECIAL COMMITTEES

Summer Meeting, 1920

F. B. Ortman, Chairman
H. T. Bellamy
E. A. Brockman
W. D. Gates
J. W. Hasburg
R. K. Hursh
C. H. Jones
L. H. Menne
B. S. Radcliffe
F. L. Steinhoff
W. W. Wilkins

Joint Committee on Ceramic Research with National Research Council

A. V. Bleininger, Chairman
P. H. Bates
A. L. Day
R. T. Stull
E. W. Washburn

REPORT OF THE BOARD OF TRUSTEES 1920--21

The Board of Trustees is able to report a year of strenuous activity and a satisfactory financial situation. The accession of a large number of Corporation Members in 1919 added a considerable amount to the receipts of that year and enabled an important sum to be added to the investment fund. Such accessions are of course not of constant occurrence, but nevertheless the Society has met the obligations of the year, including over $1,100 to complete the publication of the Collective Index to the Transactions, and the accounts show a cash balance of $1,762.50.

In addition to the meetings at Philadelphia the Board met at the summer meeting in Chicago and transacted some important business especially in relation to the editorship of the Journal, one outcome of which has been that Dr. Washburn has accepted the position. Mr. Staley, who had been editor for the past year, was compelled to resign owing to a change of business which demands his entire time. The Board places on record its appreciation of the work of Mr. Staley during one of the most important periods of the Journal's career.

As in former years, most of the work of the Board has been carried on by mail and wire and their activities have been duly published in the Journal. The standing committees have continued their useful work and each will render a report in due form. The Board gratefully acknowledges the value of this work without which the functions of the society could not have been effectively performed.

The Industrial Divisions have carried on their special work. The Glass Division organized the tour of the English Society of Glass Technology which occurred last summer and successfully performed the arduous duties connected therewith.

The Divisions of Enamels, Glass, Refractories, and Terra Cotta have each added new names to the membership list and have prepared valuable programs for the present meeting. The Enamels Division has held an especially successful membership campaign, and the untiring efforts of the secretary, Mr. Danielson, are appreciated.

The new divisions which were projected last year have not yet fully materialized but they have not been neglected and plans for the fulfillment of the organizations have been gradually maturing. Conferences will be held on this occasion upon the organization of Divisions on White Wares and Heavy Clay Products, while a new development has arisen in a projected division of Ceramic Decorative Processes under the leadership of Mr. Leon V. Solon and Mr. Frederick H. Rhead.

The program presented at this meeting while not quite as large as that of last year differs mainly in the fact that the program of 1920 contained nearly 40 papers which had been published in the Journal, while the present list contains less than half as many. The new papers are in number considerably in advance of those of last year.

The Society was represented at the Chemical Exposition held in New York in September by a booth at which the Assistant Secretary was in constant attendance. The account of the meeting has been published in the Journal. The Board is of the opinion that provision should be made to continue this representation which is an excellent form of advertisement and that there should be provided a booth, roomy enough to form a real headquarters for members who are visiting the Exposition.

The membership list displays some changes. During the war period many members were carried on the honor roll and the policy was to retain every name which might possibly prove valid. It has now been thought desirable to bring the roster up to date by removing the names of those who are in arrears.

There have been four removals by death. Ernest Mayer, who passed away on December 13, 1920, was a charter member of the Society and the fourth president. He will ever be remembered as a man who was always ready to help a fellow-worker out of his difficulties and who was sought far and wide by those in trouble.

Robert T. Hall was a prominent manufacturer of East Liverpool and will be remembered from the fact that in company with Mr. Thomas H. Sant he secured 26 Corporation Members from the Ohio pottery companies.

Henry Schmidt was a young New York salesman whose genial presence was in constant attendance at the meetings and who rendered most efficient help in the organization of the activities connected with the Chemical Expositions in New York.

J. M. McClave was the general manager of the American Fire Clay and Products Company of Cleveland. He was well known at the meetings of the Society and his absence will be felt.

The Board places on record its appreciation of the work of the membership committee under the able leadership of the Chairman, Mr. F. H. Riddle. No membership has been allowed to lapse without one or more personal letters and in numerous cases these have been successful, bringing in the arrears of two and even three years. Two Corporation Members who had tendered their resignation were induced to withdraw the action. It is gratifying to note that a letter has been received from a firm of manufacturers stating that the information obtained through the pages of the Journal is worth many times the amount of their corporation membership. Two corporation memberships have been received from India.

The Summer Meeting was held in Chicago in August and the arrangements were admirably carried out by a local committee under the chairmanship of Mr. F. B. Ortman. There was a large attendance and a thoroughly enjoyable time was spent. It was hoped and expected that the English Ceramic Society would send a delegation to this meeting but the adverse rate of monetary exchange made it impracticable for the party to cross the ocean.

A departure has been made this year in sending out bills for dues on January 1st, instead of waiting for members to pay at the annual meeting. This has greatly increased the work of the office during the past two months, but the clerical work of this meeting will thereby be relieved. About $7,000 has already been received, which of course is placed to the credit of the current year.

The Society now has $9,938.58, invested in government securities, of which the par value is $10,700, and from which the income has been $413.64 during the year. The full financial statement is appended.

Including those regularly supplied to members and subscribers an average of 1426 copies of the Journal have been distributed monthly. The publication was brought up to date in the summer months, and this has since been the rule. The Board in consultation with the Committee on Publications has decided to print 2500 copies in 1921 so as to be sure of an adequate reserve.

The Collective Index of the 19 volumes of Transactions has been completed and was published in December. The total cost is $1,585.40. One hundred forty-three copies have already been sold at $1.50 each, and many commendations of the value of the work have been received. This expenditure is of course an investment which will gradually be repaid as the edition is disposed of.

The Board acknowledges the debt of the Society to the local committee who have carefully and thoroughly supervised the arrangements for the present meeting, and have thus greatly contributed to the comfort of those in attendance.

The Board has given continued consideration to the question of the appointment of a full-time Secretary-Editor. Careful study has been made of the functions of the Society and of the manner in which these have been met by the present mode of management. The Board is not prepared to admit that the work has failed. The function of publication is in itself an important stimulus to research and the general meetings as well as those of the Divisions and Sections offer valuable means of inter-communication. In fact the Society is a clearing house of technical and practical ceramic information. The Board is not of opinion that the appointment of a full-time Secretary would necessarily improve any or all of these activities or lead to others. Furthermore, the additional annual expense would certainly not be less than ten thousand dollars and the Board does not feel that the step would be justified in the present state of the available funds.

Financial Statement for Year 1920

Receipts

Balance in checking account, Jan. 10, 1920	$ 1,262.30
Certificate of deposit, Jan. 10, 1920 (see p. 34, 1920 Year Book)	5,000.00
Dues and fees, Active, Associate, and Corporation, including Division allotments	9,606.85
Volumes of Transactions sold	1,338.98
Subscriptions to Journal	1,312.01
Advertisements	5,259.00
Reprints	211.80
Seger's Collected Writings	262.50
Branner's Bibliography	12.66
Directory of Dealers in Ceramic Materials	7.00
Collective Index to Transactions	87.00
Partial return of insurance premium	3.78
Interest on Liberty Bonds and Treas. Certificates	413.64
Balance refunded from $5000 investment	61.42
Refund on Annual Meeting 1920	200.00
Miscellaneous	33.39
Total	$25,072.33
Bank charges for exchange and lost checks replaced by duplicates	23.16
Total amount transmitted to Treasurer	$25,049.17

Disbursements

Salaries	$ 4,329.91
Publishing Nov. and Dec. 1919 Journals	1,132.01
Abstracts. Nov. and Dec. 1919	157.25
Reprints. March, Oct., Nov., Dec., 1919	163.90
Publishing Jan. to Nov., 1920, Journals	6,752.47
Abstracts. Jan. to Nov., 1920	530.32
Reprints Jan. to Oct., 1920	461.80
Copyright. 12 issues, 1920	12.00
Expense of meetings	515.92
Collective Index to Transactions	1,129.10
Insurance, storage and purchase of volumes	358.66
Secretary's office equipment	102.05
Secretary's office expense	781.17
Editor's office expense	166.52
President's office expense	7.10
Treasurer's office expense	29.02
Traveling expense	711.53
Chemical Publishing Co. for Seger	218.46
Committee expense	385.57
Division expense	
Enamels	149.46
Glass	94.41
Refractories	2.75
Terra Cotta	7.75
White Wares	3.50
Dues and fees, charged by bank for lost checks	21.00
Foreign exchange charged by bank	2.16
Dues to International Chemical Union	13.42
Miscellaneous	70.62
Investment in Liberty Bonds	5,000.00
Total	$23,309.83
Amount paid out from University Bank for exchange and lost checks	23.16
Total	$23,286.67
Free balance in bank at Urbana	1,762.50
Total	$25,049.17

Membership

Accessions in 1920

Corporation Members	18
Resident Associate Members	176
Foreign Associate Members	30
	224

Losses in 1920

Deceased	
Resident Active Members	2
Resident Associate Members	2
Resigned	
Corporation Members	3
Resident Active Members	2
Resident Associate Members	35
Dropped for non-payment of dues	
Resident Associate Members	39
Foreign Associate Members	2
	85
Transferred from Associate to Active	110

Status, February 11, 1921

Honorary	3
Life	2
Active Resident	294
Active Foreign	14
Associate Resident	821
Associate Foreign	109
Corporation	105
Total	1348

Respectfully submitted,

CHARLES F. BINNS, Secretary.

PRESIDENTIAL ADDRESS

"Some Problems To Be Solved"

As we close another year in the progress of our Society it seems worth while to pause for a moment and briefly review the aims and accomplishments of the past year before proceeding to a consideration of the problems before us. Early in the year the present administration formulated a number of objects which might represent some progress for the year's work. First, the expansion of the Journal to cover a broader field and the enlarging of the abstract department to bring to the members the benefit of every published treatise in the ceramic field. Second, the drafting of a complete Constitution and By--Laws to replace the existing Rules, which are no longer in keeping with the growth and operation of the Society. Third, placing our Journal advertisements upon a strictly business basis by handling them through an experienced solicitor in order to make the Journal self-supporting. Fourth, the broadening of our activities to include other phases of the industries allied to the strictly technical, including co-operation with our Federal bureaus on important investigations, and co-operation with other technical organizations. Fifth, the development of a series of sessions at the annual meeting of the Society and the various divisions for the presentation of data upon the practical factory problems. Sixth, the formation of the White Wares Division and the extension of the activities and membership of the Society to include the Heavy Products Manufacturers and the Decorative Arts allied with ceramics.

When we last met our industry was passing through the peak of a very prosperous period. Since then the country has gone through one of the most precipitate business recessions in its history. In spite of the adverse conditions our Society has progressed. We have grown in membership, to the extent of more than 10%; we have finished the year with a substantial financial balance in spite of greatly increased expenditures; we have improved the Journal and laid a solid

foundation for our business affairs: through the Industrial Divisions we are emphasizing the value of co-operation among the related industries; we have developed a greater spirit of progress and we are proving by our works that our Society is of increasing service to the ceramic industries.

Shortly before our last meeting in a letter to the members of the Society the following statement was made: "America was not prepared for war. The past year has shown that we were even less prepared for peace. The real problems of peace are before us and they will be more difficult ones than were brought by the war. The right spirit of co-operation among the members of the American Ceramic Society will enable the industries represented to successfully prepare for any and all problems which the future may bring." In the belief that our country now faces a period in which industrial competition will be much more severe than at any time during the past twenty years it seems well to consider some of the problems whose solving will aid in elevating our industry to a higher plane of efficiency and success.

Technical Problems

When we consider that oxygen, silica and alumina form approximately 85% by weight of the elements of the earth we can form some conception of the magnitude of the foundation upon which the ceramic industry stands. In spite of much theorizing and experimental work by mineralogists, physicists, and chemists there is comparatively little known of the real nature of the constitutions of the silicon compounds, which form such an important place in the inorganic world. Through the application of extensive scientific investigation to these materials many industries would be benefited and no doubt new ones created. The past two decades have seen an enormous development in the chemistry of the carbon compounds. It is not unlikely that the future will see a similar development in the chemistry of the silicon compounds. All the reactions involved in the processes employed in the conversion of raw materials into finished ceramic products depend upon the fundamental laws of chemistry and physics, and real and last-

ing success can be achieved only as our work is in harmony with these laws.

Although the ceramic industry in some branches antedates possibly any other modern industry it has been the slowest to make use of applied science in solving its problems. This is no doubt largely because the industry itself had developed as far as it could on empirical lines before modern chemistry was discovered. For this reason it held to its traditions and persisted in holding aloof from all technical and scientific applications. Until recent years we were content to drift along, but the pressure from foreign competition which was felt before the war caused many a manufacturer to realize that secretly guarded methods were no barrier against technical competition. The war caused us suddenly to realize that our former slipshod methods of inefficient individualism were no match, industrially, for the thoroughly organized technical team-work of German industry.

The war proved a powerful stimulus to research work in our industry, especially in glass, refractories, porcelains, and in the search for raw materials to substitute the foreign ones previously used. However, the ceramic industry can never be raised to the highly technical development of many other industries because of the very nature of our raw materials. Instead of having raw materials which are chemically pure and subject to exact chemical control we are dealing with impure and often constantly changing compounds and mixtures. It is because of these conditions that our industry is in need of every means of technical control available and it will never be possible to regulate its processes by purely mechanical or automatic methods.

The problems with which we must deal are chemical and physical on the one hand and mechanical and human on the other. From the chemical and physical standpoint we are weak in fundamental data. In fact, until the war, at least, America has not done a great deal of fundamental research which can be said to be advancing the sciences. In spite of our intensified work on dyestuffs our processes are still so undeveloped and costly that the du Ponts have recently found

it necessary to employ two German dye experts at very large salaries. During the war our Government was deluged with inventions and suggestions, but the records of one board show that more than 95% of all the inventions examined were without military value. Another board examined sixteen thousand plans and devices submitted by so-called inventors, and of them all only five had sufficient merit to warrant further consideration. It is evident that our fundamental problems can be solved only by men highly trained in chemistry and physics.

Among some of the general problems involving certain fundamental laws may be mentioned those involving the drying and firing of clay products; heat transmission and heat losses; problems of combustion, which include the whole process of kiln construction, kinds and forms of fuel, and the firing methods and controls. Many of these, and related problems, are, of course, works problems, but they are all based upon laws about the operation of which we have little knowledge and data.

Each industry has its own peculiar problems. The glass manufacturers need knowledge of the chemical reactions and the physical properties involved in the use of different materials and compositions. They are interested in learning more about heat treatment, annealing, solubilities, etc. We should know more of the actual chemical constitution of glasses, and whether we are dealing with definite compounds or mixtures. A study of the comparative chemistry involving the differences in the physical and chemical properties of the various primary and secondary forms of silica has hardly been more than outlined. Exact knowledge of the conditions and the temperatures governing their transformation would be of great importance to the ceramic industry, especially for silica brick, quartz glass, and porcelains.

There is also a great need for investigation into the constitution and properties of glazes and their relation to ceramic bodies of various compositions. The collection of data which will give a better understanding of the problems of crazing and its control is highly important. Much remains to be

done in learning the relations between the compositions of glazes and frits and the solubilities of lead glazes.

In the field of refractories there is much room for improvement and development. Further high temperature work in laboratory and plant is dependent upon corresponding development in refractories. The increase in efficiency in kiln construction and firing methods rests largely upon suitable refractories. A possible great field in clay refractories lies in the utilization of undergrade kaolins. Among the artificial refractories the future promises great advancement in the use of sillimanite, aluminum, zirconia, magnesite, and carborundum. All of our industries which have need for saggers and slabs recognize these as one of the vexing problems calling for solution.

Both the glass manufacturers and the refractories manufacturers are in need of data which will lead to standard specifications for glass house refractories. To date considerable work has been done toward arriving at satisfactory specifications pertaining to porosity and volume change of blocks, and softening points of pot clay mixes. Other data needed are those pertaining to hot bending of pot clay bodies and pot arch heating schedules. Much remains to be learned regarding the fluxing action of glasses and their various ingredients on the clay pots and tank blocks. More data on the casting of glass pots and tank blocks should prove of great value. This method is used in many plants abroad and is claimed to be much superior to the old method of pressing. Such data and the resulting specifications can be worked out satisfactorily only by co-operation between our Glass and Refractories Divisions. Such specifications as are formulated by the joint action of the Standards Committees of these two Divisions, acting in conjunction with our Committee on Standards, would have the authority of the Society.

Other problems requiring investigation are those involving the disintegration of clay products from weathering, the dunting of sanitary and terra cotta bodies, the failure of refractories under load, and the improvement of porcelains for high tension work.

Then there is the question of plasticity of clays. While there are many theories as to the cause of plasticity little is actually known. It seems fairly evident that this property is more or less connected with the water of constitution. A thorough study of this question would throw light upon the methods by which plasticity might be artifically increased. This is a most important question in relation to our white wares industry, where the use of more plastic china clay and kaolins would permit the elimination of ball clays. In a general way we have not greatly improved the quality of our pottery wares, and in order to manufacture a product that compares favorably with the European hard porcelains ball clays must be omitted from the body. In this connection also may be mentioned the importance of further investigation into the field of colloidal chemistry and its bearing upon ceramic processes.

Our White Wares Division should have a committee to investigate new deposits of raw materials and collect data that will lead to specifications for clays, flints, spars, etc. Our manufacturers do not have the knowledge and control of their raw materials that is necessary for exact control methods of production. This is especially noticeable in comparison with European methods where all materials are purchased in the crude condition and all sorting, refining, grinding and blending is done at the works.

Mechanical Problems

In all the ceramic industries there is great room for advancement and improvement in mechanical equipment of all kinds. In most of the plants now in operation mechanical means of transportation in various stages of the process could be used to advantage. Especially in the heavy, crude products industries is it desirable to perfect the entire system to more closely approach automatic procedure with the greatest possible elimination of labor. In Germany there is a plant now in process of being equipped with automatic machinery by which, it is claimed, finished brick will be ready for shipping just six days after the raw clay is dumped into the brick ma-

chine. The brick are made by the stiff mud process, mechanically placed upon cars which automatically move into a humidity dryer where they are dried in eighteen hours. From the dryer the cars move into a tunnel kiln and are fired in less than 96 hours.

In the pottery industry there is need of further labor-saving machinery. Among these might be mentioned the automatic batting-out machine as used in England and Germany, the casting machine used in England, and the automatic cup jigger used in Germany. There is also need for more mechanical conveying methods. Perhaps one of the important problems needing solution is that of a continuous, or semi-automatic filter-press, eliminating the cloths. There are a number of semi-automatic or semi-continuous filter presses in use for handling mine sludge, paints, and other non-plastic materials but they all fail when tried with plastic clays.

In England there has been perfected recently a semi-automatic machine for de-watering and classifying clays, which is known as the Gee Centrifugal Separator. This machine works on the centrifugal principle and while it is entirely successful in removing the water from a clay slip it has the unfortunate fault of also grading the materials into sizes. One large china clay company is at present using this system for preparing its clays for the market. For certain cruder clay products this system might be of considerable value.

During the war cotton fabric became so scarce in Germany that elaborate experiments were conducted to perfect a process that would replace the press using filter cloths. Exhaustive tests were made with the various types of centrifugal machines and they were finally rejected, as it was found that too great separation of the constituents of the body took place. The same conclusion was reached regarding all machines depending upon the suction and vacuum principles. Repeated investigations with different methods of operation achieved no success, for it was found that the greatest possible vacuum was not sufficient to remove the water as soon as a thin layer had formed in the apparatus.

The electro-osmose system has been sufficiently developed that there is no question but that it will de-water clays without any resulting separation of sizes. At the present time this method is entirely too costly for practical application in factories on account of the cost of installing and the expense of operating.

One of the most interesting continuous filter machines consisted of a column of thin metal rings held by bolts, by which they could be held together tightly or loosely. This sheet metal column is set in the middle of a cylindrical drum and tightly closed. The slip is fed by pressure into the space between the drum wall and the disc column. The water is forced between the discs to the inside of the column while the filtered material collects on the outside of the column. The economical advantages of such a machine are evident and without doubt a continuous filtering apparatus of some sort is a certainty in the near future.

Standardization

The question of standardization of many of our methods and products deserves serious consideration. In every line there is a multiplicity of designs, shapes, patterns, and sizes which might well be restricted by the proper co-operation. It was only through the war that we began to realize the waste through unrestricted duplication in production. The Refractories Manufacturers Association has begun the systematic standardization of their products and they are just beginning to realize the importance of this work and the benefits that will result. Our Refractories Division should co-operate with them on their problèms.

In the sanitary industry there are many manufacturers making many different styles of many different articles. In each case a great deal of duplication is constantly adding to the cost of production. Then again we find many jobbers handling metal fixtures made to their own designs and sizes without regard to any standards. In the glass industry the necessity of standardizing certain wares is of urgent im-

portance. In the item of bottles and jars alone there are now between four and five thousand different sizes, shapes and kinds being marketed. Much of this output is used for marketing food products and the manufacturers should take the initiative instead of being compelled by the consumer to standardize these containers. In all of these matters the Standards Committees of our various Divisions might well supply the initiative.

Standardized Methods

We may well profit from the German industrial example in standardized methods of manufacture and mass production. This scientific organization, together with the intense application of scientific methods to factory production, has been the secret of Germany's rise in the industrial world and her rapid exploitation of the world markets. The inevitable outcome of standardized manufacture and mass production, if carried to its ultimate conclusion under our present system of distribution, is over-production. This was the result of the German system of producing first and finding the market afterward. We need not adopt it in its entirety with the insatiable desire to constantly lower costs which could only be achieved by constantly increased output. However, standardized methods based upon scientific principles will eliminate much waste and loss without carrying production to excess.

Research and Development

No engineer who has traveled in Germany and studied her industries can fail to realize that her great strength in commercial expansion, and in war, was due to the solid foundation of her organized research. Their industrial plan was fundamentally based upon research and organization, and her industries were designed for constant growth. Her technical and scientific men were considered the industries' greatest assets and there was the closest co-operation between all related branches of any industry. Germany has held science in the highest esteem, and while she has been less inventive than

other countries she has labored unceasingly. She has excelled in perseveringly perfecting and applying scientific control of all methods of production. It is interesting to note that in every industry the processes are all under the control and direction of technical men. The plant is run in absolute co-ordination with the laboratory; is, in fact, a huge laboratory. This, coupled with exact and intensely serious labor, accounts for their success against such great odds.

For our purposes deductive work in the basic sciences, chemistry and physics, is the most important. To do this requires extensive and costly apparatus which very few individual firms can afford. We must, therefore, turn to the government and the university laboratories. I would earnestly urge that this Society and the members of its various branches make definite plans for closer co-operation with these organizations. I cannot but feel that in the past there has been a lack of co-operation between our governmental and university laboratories themselves on the one hand and between them and the industries on the other. There would also be less duplication of effort, for often different laboratories are doing the same work. The number of investigations and their equipment is so limited and the field is so large that all efforts should be directed without waste.

Last year it was my desire and hope that the Society might officially make some investigations in conjunction with our Federal Bureaus. Upon being approached it was found that they either were too busy with other problems or they had not the time, or men, or money to co-operate. If these bureaus do not have the men it is because they do not have the money, and if they do not have sufficient money it is entirely because the industries that would be benefited do not make enough effort to help finance them or to see that they receive adequate appropriations.

Another great strength of the German industrial system was in the practical application of their scientific discoveries. It is useless to work out fundamental laws unless they are applied. In many German factories we find that the director is a college professor, devoting a part of his time to research, a

part to applying his science in the plant and a part to instructing future scientists. By the proper co-operation between our Society and our federal organizations we would be solving the problems which TODAY are retarding the industry.

For one thing might be mentioned what could be accomplished by the proper co-operation between our Society and the heavy products manufacturers. They have many problems to be solved, many of them similar to other branches. While their operations are based upon certain laws it would seem that the strict application of fundamental principles does not apply nearly so much as the solution of engineering difficulties. On account of the widely varying raw materials used in these industries the chemical and physical problems must be handled for each individual case. However, there are many engineering problems whose solution would greatly benefit the whole industry. For example, we need comparative data upon the results of the tunnel kiln and the continuous compartment type of kiln. We need to learn many things as to the type of kiln best adapted to different wares.

We need more investigation into methods of eliminating fuel waste in the firing of kilns already constructed. Many manufacturers cannot afford a continuous or tunnel kiln but must struggle along with existing equipment. Again, a tunnel kiln is so unsuitable to many existing plants that the saving in firing is offset by other adverse factors in operation.

There is also need that more attention be paid to the designing of plants and layout of machinery to effect the greatest possible efficiency of operation. Problems of this kind can better be worked out with the aid of construction and fuel engineers in co-operation with actual plant management than in the laboratory and there is no reason why this Society should not be the means of this co-operation.

Ceramic Training

In this connection it may be noted that we do not seem to be training men with the care that we should. Very few of our ceramists are competent to do real scientific research

work on account of the lack of proper training in chemistry and physics. On the other hand we do not take into consideration the executive and business side of the industry as fully as we should. Our graduates seem to have the idea that their training in ceramics has thoroughly fitted them for their life work. As a matter of fact success in industry depends more largely upon personality and business ability than technical knowledge. The men who have done successful research work have done it because they have continued as students. We should begin to direct our training of the technical men with a view to whether they will become research chemists, ceramists, engineers, or executives. This can be done only by close co-operation between the universities and the industries. We would profit by the German system where the factory is open to the university students to do research work on any problems, and to thoroughly grasp the application of science to practice.

Economic Co-operation

While our Society exists primarily for scientific and technical advancement, yet every individual member is influenced by economic conditions. The need of industry today is a market for full production and this cannot be created without foreign trade. There seems to be a strong impression today that what is needed to promote business is the erection of high tariff walls. We need to realize that foreign trade can exist only through the exchange of goods, and that the economic recovery of Europe is of vastly greater importance than high tariffs. The inability to trade with us means the economic collapse of Europe and this country cannot conceivably avoid the effects of a serious depression in the countries so adversely affected by the war. I would earnestly urge the members of this Society to give this question their most careful consideration before advocating a restrictive policy which will seriously hinder business recovery.

Industry faces a period today that will be quite different from the one just past. The most difficult problem of the past four years has been the labor problem. The big problem

in the immediate future will be that of management. In the development of our industrial system we have perfected the mechanical processes and largely forgotten the human element. We constantly hear of the antagonism between capital and labor and forget that the most important element in the system is management. Management represents the connecting link between capital and labor and is today probably the weakest member of the organization. The question of increased efficiency and lower costs is very largely a matter of mental attitude on the part of the worker. It is time for the leaders to find a means of conveying to the minds of the workers their own ideas and implanting the spirit of co-operation and the knowledge that by increased production only, can increased consumption be made possible. The question of the enlightened management of men in connection with efficient development of methods looms up as a large field for our engineers.

Perhaps the most important problem pressing for solution today is that of unemployment and continuous normal business. This is essentially an economic problem that can better be solved by engineers and business men than by politicians. Its solution is almost certainly dependent upon a drastic cut in government expenditures throughout the world, and this in turn is entirely dependent upon reduction of armaments. From the standpoint of human needs there is no reason why Industry should not continue to produce on the same scale as during 1917 and 1918. The whole world is in need of more goods and to fill this need and raise the general standard of living to a desirable plane would mean almost indefinite prosperity. Our economic structure collapsed because our financial system of exchange has failed, owing to unlimited expenditures. The huge cost of running the governments of the world through the war has made the overhead load so heavy that business is no longer able to carry it.

A concrete example of the present lack of constructive legislation is the chaos in the housing situation. The most logical means of transition from the present depression to normal conditions would be through the recovery of the building

industry. About forty percent of the ceramic industries would be directly affected by this, and much more indirectly. Yet we find Congress preparing to spend hundreds of millions of dollars upon increased armaments while they have not one constructive plan for solving the housing shortage. Here is a splendid opportunity for concerted co-operative action of all the organizations affected in formulating a definite, constructive plan and carrying it to a conclusion.

The Function of the Society

Recently there has been some discussion as to whether the Society is living up to its opportunities and properly filling the needs of its members and of the ceramic industries at large. It is stated that the principal, if not the only, function of the Society at present is the publication of the Journal, and that a great deal more might be done if its energies were properly directed.

There is no doubt but that the original function of this Society was to bring about a closer personal co-operation between the men engaged in the ceramic industries and to spread their knowledge through publication. If publication were impossible, except at great expense, it is obvious that a great amount of research and investigation would remain undone, and the greater part of what is done would not be generally available.

The function of publication is unquestionably an important one. In fact, it would seem to be the supreme activity of the American Chemical Society and of many other scientific and engineering societies. Thousands of men belong to these associations for the sole purpose of keeping in touch, through their publications, with the activities of others in their own field of endeavor. The first step in any investigation is to examine what has already been done. This can only be done through existing literature.

The function of the organization of meetings should not be underestimated. Every member who attends our meetings both of the Society and of the Divisions and Local

Sections, knows that he gains much through personal discussions, the renewal of friendships and the making of new acquaintances, that cannot be had in any other manner.

The question of the nature and extent of the activities of this Society is one which the members should consider and determine. The decision is squarely up to the members themselves and I am sure that the Board of Trustees would welcome a full expression of opinion from every member. In this connection it should be remembered that the members **are** the Society, and the Society as an organization can give only as it receives.

I have attempted to point out some of the problems calling for attention and to suggest some of the ways in which our work may be directed. We have in our organization the necessary foundation upon which to build according to any plans which our members are willing and determined to carry into execution.

Conclusion

In closing I wish to express my appreciation of the confidence placed in me by the members of this Society in honoring me with this office. While the work has occupied a considerable part of my time and thought, it has been a pleasure to be of some service. I want to thank the members of the Board of Trustees for their splendid co-operation at all times, and particularly do I want to express my appreciation of the support and assistance of the Secretary and the Assistant Secretary. I owe much to many of the members who have worked on committees and otherwise contributed to the work. As I step back into the ranks I do so with the desire that my experience may be of further use to the Society in all ways that may seem best, for I have no higher ambition than to help promote the interests of the American Ceramic Society and through it the Ceramic Industries of America.

REPORT OF THE COMMITTEE ON PRESIDENTIAL ADDRESS

The Committee respectfully submits to the President and Board of Trustees the following report on the Presidential address of Mr. R. H. Minton, made before the Society at the annual meeting held in Columbus, Ohio, on February 21, 1921.

Taking up in their order the suggestions made, we find:

First:—That the expansion of the Journal is being cared for by the Committee on Publications.

Second:—A new constitution and by-laws is in course of preparation.

Third:—The extension of advertising in the Journal is being properly cared for and has been placed in the hands of a competent advertising man.

Fourth:—The suggestion that the Society more closely co-operate with the Federal Bureaus on investigations is an important one. We believe that suggestions for these investigations should come from the chairmen of Divisions or Division Committees and be submitted to the Committee on Co-operation, or the Committee on Research and Development.

This Committee should attempt to have the Federal Bureaus, Technical Schools and Research Laboratories take up these problems, so that there will be no duplication and so that the industries affected will have their most troublesome problems worked out first. When a problem has been assigned, a committee should be appointed from the division interested, composed of men in close touch with the practical side, to act in an advisory capacity if called upon.

Fifth:—Sessions on practical factory problems can best be held by divisions at their regular meetings by the question box method. Any important results can be published in the Journal.

Sixth:—The formation of White Wares, Heavy Products and Decorative Arts Divisions is already under way.

Technical Problems

It is suggested that the various Divisions be asked to devote a meeting during the year to outlining the most important problems before the industry they represent and that this list with any suggestions, be presented as early as possible to the Committee on Co-operation or the Committee on Research and Development, for their action.

Mechanical Problems

It is suggested that a general session at the annual meeting be devoted to mechanical equipment, an effort being made to have the equipment manufacturers present their problems at that time. Practically every Ceramic equipment manufacturer in the country holds membership in the Society, but they have been given no encouragement to present papers, in the belief that advertising was uppermost in their minds.

The equipment manufacturers have received very little help from either the industry or the Society and much good can be done by the Society in fostering closer relations.

Standardization

While the standardization of manufactured products may properly be considered as belonging to the trade associations of the various industries, it is suggested that the Society actively offer its co-operation in all matters of standardization in which it might have an interest.

Standardization of Methods

In this matter also it is suggested that the Society take a more active interest. It is to be assumed that the trade associations will welcome any assistance the Society can give them.

Research and Development

It is a well known fact that our Federal Bureaus and State University Research Laboratories are hampered in their work by lack of money. It is the belief of the Committee that this condition can be bettered, at least, by an organized effort on the part of the Society to influence the granting of a larger appropriation for research purposes.

A few years ago the Ceramic Section of the Bureau of Standards was brought into being largely through the organized efforts of the Society, and larger appropriations can also be obtained by using the same methods.

With a technical man of high standing at the head of the Department of Commerce, this should be made much easier, but nothing will be accomplished unless the Society acts.

Function of the Society

It is the opinion of this Committee that the larger purposes of the Society include not only the holding of meetings and the publication of the Journal, but also embrace active co-operation with other Societies and organizations and the stimulation of Research through co-operation with the National Research Council. It is suggested that the Board of Trustees consider ways and means for fulfilling these purposes either through the better organizations of the present Committees or by the appointment of an officer of the Society who can give his full time to the work.

Respectfully submitted,

A. F. GREAVES--WALKER,
Chairman of Committee.

Approved by entire Committee.

COMMITTEE
A. F. Greaves-Walker, Chairman
E. Ward Tillotson
E. P. Poste

Pittsburgh, Pa., May 6, 1921.

REPORTS OF DIVISIONS, 1920--1921

Enamels Division

The Enamels Division during the past year has made marked progress both from the standpoint of membership and of awakened interest in the necessity and desirability for co-operative investigation of the problems of the industry.

The enrollment of the Division as reported at the last meeting of the Society was as follows:

Active members	10
Associate members	63
Corporation members	8
Total	81

The enrollment on Feb. 15, 1921, was increased to the following number:

Active members	16
Associate members	106
Corporation members	8
Total	130

During this period there was taken from us by death, an active supporter of our Division, Mr. Schmidt. There were three resignations consisting of two corporation and one associate member. The total net increase, therefore, was 49 members or 60 percent as compared with an increase of about 30 percent for the previous year. This increased membership is due to the activities of individual members of the Division coupled with the work of the Divisional membership committee which has accomplished much through circular letters and personal appeals, reaching all those interested in the industry.

The work of the Division has been made known to the industry by four circular letters, which have also been a valuable adjunct in interesting enamelers in the Society.

The Division held one special meeting during the year in conjunction with the Sheet Metal Ware Mfgs. Association at the Bureau of Standards, Washington, D. C., to consider the work of the Bureau on Fish Scaling. A committee of the Division has also co-operated in the application of these results to actual manufacture.

The efforts of the Program Committee of the Division has resulted in the preparation of a program of 16 papers for this meeting, the largest number ever presented at a gathering of this Society and highly gratifying in that all branches of the industry are represented.

All indications point to another year of increased growth and interest in this division.

Respectfully submitted,

R. R. DANIELSON, Sec.

Glass Division

This year has been one of great importance for the Glass Division and for the whole Society in that it has established a precedent in international co-operation. The invitation for the joint meeting extended last year to the British Society of Glass Technology was accepted by that Society and a delegation of 33 came to this country for the conference. A formal report of this meeting has been returned to Secretary Binns and has appeared in an abbreviated form in the Journal.

This joint meeting rather overshadowed the other activities of the Division and was probably the cause of a lessened activity in general Society affairs. For example the new membership of the Division has shown a comparatively small increase (17%) and over half of this is due to new foreign members. It is to be pointed out in this connection that new members cannot be secured by writing letters or by other efforts of a general nature and that only personal solicitation is effective. In addition to the voluminous correspondence the Secretary has sent six circular letters during the year to all members of the Division.

The condition of the treasury is as follows:

Receipts		Disbursements	
Balance from 1919..	$ 93.99	Disbursements for the year..	$158.29
Receipts for year...	128.25	Balance	63.95
	$222.24		$222.24

Respectfully submitted,

E. WARD TILLOTSON, Sec.

Refractories Division

There were no special meetings of the Division during the year, nor was there occasion for a great number of circular letters. The membership however, has increased from 100 to 124, and its activity may be best judged by its permanent record. Sixteen of the 76 original technical articles appearing in the Journal were on the subject of refractories and constituted 190 of the 740 printed pages. This is the equivalent of three complete issues. The Division lost the services of Mr. A. V. Bleininger as Chairman before his second term was completed, but was fortunate in securing Mr. A. F. Greaves-Walker for the remainder of the year.

Respectfully submitted,

R. M. HOWE, Secretary.

Terra Cotta Division

This division has finished its second year showing very satisfactory progress. We have fifty-seven members, all of whom are associated with the terra cotta industry.

We have ten papers and discussions for submission at this meeting on important subjects pertaining to the terra cotta industry.

By far the most important work now being carried on by the division is that which it is doing in conjunction with the National Terra Cotta Society. This society made quite a large

appropriation to be used for research work in co-operation with the Bureau of Standards and the Terra Cotta Division. The work is now well under way and we hope by the next meeting to have some important results for submission.

The financial standing of the division is as follows:

Cash in bank	$40.00
Credit with the secretary of the American Ceramic Society	39.50

Respectfully submitted.

R. L. CLARE, Secretary.

REPORTS OF LOCAL SECTIONS, 1920--1921

New York State Section

The New York State Section held one meeting during the year 1920. This meeting was held in December at Schenectady and those present were:

Edward Schramm, Onondaga Pottery Co., Syracuse
Mark Haley, Onondaga Pottery Co., Syracuse
J. B. Shaw, Alfred
E. E. F. Creighton, General Electric Co., Schenectady
L. E. Barringer, General Electric Co., Schenectady
F. Cermak, General Electric Co., Schenectady
Robert Twells, General Electric Co., Schenectady
C. C. Treischel, General Electric Co., Schenectady

At this meeting it was decided to give the New York State Section another chance for life and it was voted that each point of ceramic interest in the state should hold individual meetings. The Schenectady section held a meeting in the month of January at which twenty-five were present and much enthusiasm was evident. No other center held a meeting prior to February 1st, 1921.

Eastern Section

The summer meeting was held on June 25th, 1920, at the Trenton Country Club, Trenton, New Jersey. Attendance 80. The following very instructive papers were read:

"Superior Saggers"
C. F. Geiger, Carborundum Co.

"Recent Accomplishments in Ceramic Drying"
D. H. Applegate, Proctor & Schwartz, Inc.

"Studies on Clay in the Raw State"
A. V. Bleininger, Bureau of Standards

"The Selection of Refractories"
R. M. Howe, Mellon Institute

"Firing Wares in the Dressler Kilns"
Conrad Dressler

The annual meeting of the section will be held in March of this year.

The Executive Committee has held frequent meetings during the past year. The Eastern Section rendered material assistance in securing an appropriation of $100,000 for the erection of a new Ceramic Department at Rutgers College and has taken an active part in selecting plans for the building. Co-operating with the Eastern Section, the Eastern Terra Cotta Association has recently held a prize competition for an exterior design for the building. Fourteen designs were submitted in this competition and the plan selected for the building will conform closely with the prize-winning design.

The Section now has 190 members enrolled.

Report of the Chicago Section for 1920--1921

During the past year, four meetings were held with an average attendance of twenty-five at each session. As usual, a dinner or luncheon preceded the program. There are about one hundred and sixty-five names on our mailing list. Many of the persons so listed are located at points so far distant from

Chicago that regular or even occasional attendance at the meetings is scarcely to be expected. Of the total enrollment we estimate the active membership to be about sixty. In view of the fact that the active members are specialists and in the nature of things the papers offered are not of interest to all, but rather to certain groups, we therefore are of the opinion that the attendance has been fairly representative and satisfactory. However, it is our desire to make a better record during the ensuing year, especially with reference to stimulating more active participation on the part of those graduates of ceramic schools who are resident in our district.

The dates of the meetings and the programs presented were:

April 20—With the Illinois Clay Manufacturers' Association—

"Humidity Drying"
H. P. Matzen, Chicago

"The Enamel Brick Industry"
I. E. Hardy, Momence

May 21—

"The Enameling of Cast Iron"
L. H. Menne, Chicago

"The Preparation of Steel for Enameling"
L. G. Whitford, Chicago

November 27—

"Porcelain Enameling Furnaces"
C. G. Armstrong, Chicago

"Notes on Spark Plug Porcelain"
W. W. Wilkins, Chicago

"The Oil Gas Furnace in the Enamel Industry"
W. Rodehouse, Chicago

February 5, 1921—

"Notes on the Acid Resistance of Enameled Cooking Utensils"
B. T. Sweeley, Chicago

"Notes on the Manufacture of Lead Products Used in the Ceramic Industry"
Lester T. Wilson, Chicago

The report of our activities would be incomplete without reference to the highly successful and very enjoyable summer session of the parent society which was held in Chicago. The very elaborate program was skillfully devised and most efficiently managed under the guidance of members of this section.

In closing we wish to express our regret on the removal of Mr. F. B. Ortman from this district. Mr. Ortman always gave freely of his services for the benefit of the section and he will be greatly missed. We wish him a full measure of success in his new connection.

New England Section

The New England Section has not been prosperous if you measure it by the attendance and number of meetings; but on the other hand, the meetings which are held are very interesting, as well as profitable. Those who do attend take a very active interest in the Section's affairs and the character of the papers and especially the interest in discussions have greatly improved over that of the first few meetings. The small attendance and infrequent meetings are due to the fact that Boston appears to be the most suitable place for meeting. It is the most easily reached of any city in the state, and accommodations can be there most readily arranged. On the other hand, nearly half the members reside in Worcester, but unfortunately Worcester meetings have not been highly satisfactory as regards attendance from outside.

On June 12, 1920, the seventh meeting of the Section was held at the Norton Boat Club in Worcester. In the afternoon an inspection was made of a private collection of old American pottery owned by Mr. Gates. In the evening with 18 members present an excellent paper was presented by Mr. Browne Harding on "Fuel Oil Burners for Tank Glass Furnaces."

The eighth meeting was held January 22, 1921, at the Engineers' Club in Boston. There were 13 members present, who were privileged to listen to four very interesting papers, as follows:

"Difficulties Encountered in the Manufacture of Watch Dials" F. P. Flagg

"Notes on the Efficiency of Clay Crucibles" H. W. Richter

"A Novel Testing Furnace" S. F. Walton

"Application of Pyrometers to the Ceramic Industries" H. Goldsen

At this meeting an election of officers took place as a result of which the following men were chosen to handle the affairs of the Section for the next year:

A. T. Malm, Chairman,
S. F. Walton, Secretary and Treasurer,
M. C. Booze, Councilor,
Browne Harding and Prof. C. L. Norton,
Members of the Executive Committee.

Northern Ohio Section

During the year the Northern Ohio Section has held four meetings, at Detroit, Sandusky and Cedar Point, Elyria, and Cleveland, respectively. The interest of the members has been manifested by a good attendance, presentation of technical papers, and the courtesy of various industries.

A. F. Gorton, B. A. Rice, Max Donauer, R. D. Landrum, and E. P. Poste have given technical papers, while the Jeffery-Dewitt Company, of Detroit, and the Elyria Enameled Products Company, of Elyria, have made the Section their guest, and other companies have aided in the success of the meetings.

There have been present men well known to many ceramic industries, who have favored the meetings with information, and at all times the Section has been made to feel the hearty co-operation of the parent Society.

Central Ohio Section

The Central Ohio Section held only two meetings during the year. The first was at Zanesville on November 12, 1920. The speaker was Professor A. S. Watts, who spoke on "The

Possibilities of a Terra Cotta Industry in Central Ohio." There were about thirty present. The second meeting was at Columbus on January 18, 1921. The speaker was Mr. Gerald Fitz-Gerald and his subject was "The Application of Heat." The Section closes its year with a treasury balance of $55.47.

The officers for the year are:

M. B. CHENEY, Chairman.
J. D. WHITMER, Secretary-Treasurer.
A. S. WATTS, Councilor.

Respectfully submitted,

ARTHUR S. WATTS, Councilor.

Pittsburgh District Section

The first meeting for the year of 1921 was held in the Chamber of Commerce Auditorium, Pittsburgh, Pa., on April 20, 1920.

The following program was presented:

"A Study of Spalling"
R. M. Howe, Mellon Institute

"Corrosion Tests for Glass Pot Mixtures"
D. H. Fuller, U. S. Bureau of Standards

"Pyrometric Practice"
Dr. Paul B. Foote, U. S. Bureau of Standards

A discussion of the last paper was led by Professor H. S. Hower of Carnegie Institute of Technology, which developed much interest.

At 6:30 P. M., April 20, a farewell dinner was given in the dining room of the Chamber of Commerce Building in honor of A. V. Bleininger, who was transferring his office of U. S. Bureau of Standards at Pittsburgh, Pa., to Washington, D. C.

Hearty tribute was paid to Mr. Bleininger as a man, a scientist and as a practical aid to the Ceramic industries of this district by the speakers.

Dr. Tillotson introduced the toastmaster, Francis W. Walker, Sr. Mr. Walker spoke of Mr. Bleininger as his friend, ever ready to give assistance.

L. E. Barringer of the General Electric Company spoke of Mr. Bleininger's college days and complimented him on his ever readiness to assist his classmates.

Mr. W. E. Wells of the Homer-Laughlin China Company mentioned the many ways in which Mr. Bleininger had aided the pottery industry of the United States.

Mr. W. L. Smith spoke in behalf of the United States Potters' Association.

The many members present felt the loss to the Ceramic industry as well as to the scientific circles of the Pittsburgh Section with Mr. Bleininger's transfer to Washington, D. C.

The second meeting of the year was held at Mellon Institute on December 21, 1920.

The following officers were elected for the coming year:

J. Spotts MacDowell, Chairman
Harbison-Walker Refractories Co.

A. V. Bleininger, Vice-chairman
Homer-Laughlin China Co.

J. W. Wright, Secretary
Macbeth-Evans Glass Co.

Thomas H. Sant, Treasurer
John Sant and Sons Co.

F. W. Walker, Jr. Councilor
Beaver Falls Art Tile Co.

A report submitted by the treasurer showed cash balance on hand December 21, 1920, $44.52.

The following program was presented:

"Properties of Commercial Gases"
F. J. Denk, Pittsburgh, Pa.

"The Use of the Microscope in Ceramics"
Dr. R. Thiessen,
U. S. Bureau of Mines, Pittsburgh, Pa.

The beginning of the year 1921 showed the Pittsburgh District Section to have 87 members in good standing.

REPORTS OF STUDENT BRANCHES, 1920--1921

Ohio State University Student Branch

The Student Branch held the following meetings during the past year:

On March 16, 1920, an address was given by E. P. Poste of Elyria, Ohio, on "Enamels and Enameling of Metals."

On April 13, 1920, H. G. Schurecht spoke on "The Effect of Size of Grain in Clay Bodies."

On May 11, 1920, the Annual Banquet was held, which on this occasion was at Marzetti's Restaurant. Toasts were responded to by each member of the senior class and also by Professors Demorest, McCaughey, Stull and Harrop.

The University year ended with all bills paid and a balance of $2.50 in the treasury.

On November 3, 1920, the first fall meeting was held and the following officers elected for the school year:

J. L. Carruthers, Chairman

D. M. McCann, Vice-chairman

Willard Stief, Secretary-Treasurer

Dr. L. I. Shaw of the U. S. Bureau of Mines talked on the "Activities of the Bureau."

On December 15, 1920, Mr. Wilbur Stout discussed "Fire Clay and Its Relation to Engineering Industries."

On January 19, 1921, Dean E. A. Hitchcock of the College of Engineering addressed the Branch on "The Engineer of the Future."

On February 15, 1921, Professor A. S. Watts spoke on "The Industrial and Art Possibilities of Metal Enamels.

There is a membership of forty-three, exclusive of faculty, and the meetings are uniformly well attended. The presence of students in the Department of Metallurgy is noted with pleasure. We also have enjoyed and profited greatly by the presence of members of the Bureau of Mines technical staff.

Respectfully submitted,
ARTHUR S. WATTS, Councilor.

New York State Student Branch

The New York State Student Branch has held bi-weekly meetings throughout the year. The following officers were elected at the first session to serve for one year:

David Robison, Chairman
Charles Stamm, Secretary-Treasurer

The programs were planned by the program committee with two ideas in view; first, to bring in speakers who are actually "on the job," in order to keep abreast of ceramic practice, and second, to encourage self-expression on the part of the students.

It was accordingly planned to have a formal talk by some authority on different phases of ceramic practice once a month and at the alternate meetings to have the upper classmen report on their Summer work in ceramic plants.

The monthly addresses so far given have been as follows:

"What the Manufacturer Expects of the Young Engineer" — J. B. Shaw
"The Casting of Glass Pots" — Robert H. Sherwood, Bureau of Standards
"Remodeling a Face Brick Plant" — Howard Langworthy, Jewettville Clay Products Company
"The Manufacture of Spark Plugs" — Donald Hagar, Jeffery-Dewitt Co.

The Section plans a tour of inspection in the Spring to nearby ceramic plants. On account of the expense involved in a trip to Columbus, only three students were able to attend the annual meeting of the Society, but an enthusiastic meeting is anticipated when the Student branch meets with the Ceramic Guild (art students) for the annual banquet, when reports of the Convention are given. The Branch paid the expenses of one delegate to the Convention.

The membership is sixty and the average attendance at meetings has been forty-five.

Respectfully submitted,
G. A. BOLE, Councilor.

Iowa State College Student Branch

The Iowa State College Student Branch has held meetings twice a month on Wednesday evenings throughout the present college year.

At the first meeting J. W. Whittemore was re-elected President and L. R. Alt was elected Secretary and Treasurer. The following committees were appointed:

Program:
- Mark Taylor
- Fred W. Greenlee
- L. R. Alt

Entertainment:
- Harold Borg
- Wayne Barrett
- Robert Boyd

During the year Prof. Galpin delivered a talk on the manufacture of clay marbles, a particularly good talk. Prof. Cox told of the plans and methods of the grinding wheel plant in France with which he had been connected. J. W. Whittemore talked on the handling of a continuous kiln. Mark Taylor told of the method of manufacture of glass house tank blocks. Wayne Barrett told of tunnel kilns of the moving ware type, while the other meetings resolved themselves into general discussions of matters of more or less interest. One meeting was devoted to a Christmas tree and the cultivation of good fellowship, solely.

There is a healthy interest in the Branch on the part of the membership and it is especially pleasing to note that the underclassmen manifest the same interest as those with advanced knowledge of the work done in the field of ceramics in a practical way.

Respectfully submitted,

PAUL E. COX, Councilor.

University of Illinois Student Branch

The student branch started the year with only a small nucleus of upper-classmen to assume leadership in the activities of the society. A get-together smoker was held for the opening meeting in October which was well attended. Each one present was called upon to stand and introduce himself. The origin and purposes of the organization were explained and the relationship to the American Ceramic Society. Memberships were solicited with a fairly satisfactory response.

Four program meetings have been held during the first half of the present year at which either students or members of the faculty have spoken on subjects of interest but not entirely along the line of ceramics. A joint meeting, with the local student branch of the A. I. E. E., and a program on the subject of electrical porcelain, was planned for the January meeting but was postponed due to conflict in dates. This will be held in the near future.

The officers at the present time are:

Earl B. Baker, Chairman

Gordon Klein, Secretary-Treasurer

Respectfully submitted,

R. K. HURSH, Councilor.

REPORTS OF COMMITTEES, 1920-1921

Committee on Co-operation

1. Co-operation with the American Chemical Society.

The chairman of the Committee and one other representative met with a similar committee appointed by the president of the American Chemical Society to discuss the possibility of co-operation between the two societies. After discussion it was agreed that co-operation in the preparation and publication of ceramic abstracts could be entered into with

advantage to both societies. As a result of the report of this conference, the Council of the American Chemical Society authorized the editor of Chemical Abstracts to enter into a co-operative arrangement with the editor of the Journal of the American Ceramic Society in the preparation of ceramic abstracts. Such a co-operative arrangement has since been entered into by the two editors and is now in force.

2. Report of the Committee on Definition of the Term Ceramic.

In accordance with the action taken by the Society at its last meeting the Committee on Co-operation has assumed the duty of distributing copies of the Report of the Special Committee on "Definition of the Term 'Ceramic,'" and copies have been sent to the secretaries of the following societies:

The Society of Glass Technology

The Ceramic Society (English)

The Japanese Ceramic Society

The Syndicat des Fabricants de Produits Ceramiques de France. Acknowledgments have been received from the two English Societies.

The National Research Council has been requested by the Committee to secure through its foreign connections, a list of any other ceramic societies in the European countries.

Copies of the report were also sent to the editorial departmets of the following dictionaries and encyclopedias;

Encyclopedia Americana

Encyclopedia Britannica

New International Encyclopedia

American Year Book

Annual Register

Century Dictionary and Cyclopedia

New Standard Dictionary

Webster's New International Dictionary

3. Engineering Conference.

At the request of the Board of Trustees, the chairman of the Committee represented the Society at the organizing conference of the Engineering Societies held in Washington last

June. The chairman recommended that the Society join the new organization provided a feasible method could be found for financing its participation.

4. Ceramic Day at the Chemical Exposition

A creditable program was arranged and given on Ceramic Day, September 24, at the Sixth National Exposition of Chemical Industries. The program follows:

FRIDAY, SEPTEMBER 24TH

Under the Auspices of American Ceramic Society

12:30 P. M. Luncheon for members and guests, at Hotel Commodore, 42d St. and Lexington Ave.

2:30 P. M. Papers and discussion, Conference room

Opening Address—"The Potter's Art and the Chemist's Science"
Presented by R. H. Minton

"The Significance Attached to the Term Ceramic in Ancient and Modern Usage"

An abstract from the report of a committee of the American Ceramic Society
Presented by C. F. Binns

"A Classification of Sheet Steel Enamels" R. R. Danielson

"Refractories" H. F. Staley

"Ceramics and the People"
Charles F. Binns

"Decorative Architecture"
Leon V. Solon

"The Influence of the Artist in Industrial Ceramics"
J. Munro Hewlett

8:00 P. M. Moving Pictures, Conference Hall

"The Pottery Industry"
Courtesy of the Rookwood Pottery

"The Manufacture of Electrical Bulbs"
Courtesy of Nela Park Laboratories

Other Industrial Films

In this connection the Committee desires to express its appreciation of the work of Mr. Henry Schmidt, of the Roessler and Hasslacher Chemical Company, who acted as local representative of the Society and whose unfortunate death during the midst of the preparations for the Exposition it is our sad duty to record. The Committee is also grateful to Mr. George Hasslacher, of the Roessler and Hasslacher Chemical Company, for his helpfulness in taking charge of the local arrangements after the sudden death of Mr. Schmidt.

5. Use of Fuel Oil in the Ceramic Industries

A request from the American Gas Association for the collection of statistics concerning the consumption of fuel oil by the ceramic industries was referred to this Committee and after investigation the Committee recommended to the Board of Trustees that a suitable questionnaire be prepared and circulated to the membership of the various trade associations through the secretaries of these associations and that the replies to the questionnaire be transmitted to the American Ceramic Society's Committee on Research for tabulation, study and report.

6. Bibliography of Ceramic Books

In the August number of the Journal of Industrial and Engineering Chemistry there appeared a report of the American Chemical Society's Committee on the "Preparation of a Recommended List of Chemical Textbooks for Libraries." This report included certain recommendations with regard to books on ceramics. It seemed to the chairman of your Committee that these recommendations were most inadequate and misleading with reference to the nature and importance of the field of ceramics and the chairman therefore took the responsibility of addressing a letter of protest, in the name of the Society, to the editor of the Journal of Industrial and Engineering Chemistry, at the same time offering the services of the Committee on Co-operation in preparing a really representative list of ceramic books. This offer was accepted and such a list was prepared and published in the May number of the Journal of Industrial and Engineering Chemistry.

7. Recommendations

Your Committee has the following recommendations to make respecting the work of future Committees on Co-operation:

(1) It is recommended that the duty of arranging for Ceramic Day at the National Chemical Exposition be taken from the Committee on Co-operation and vested in a new committee appointed especially for this purpose, the chairman of which shall be a resident in or near the city in which the Exposition is held. It has been very difficult for the Committee on Co-operation during the last two years to satisfactorily look after this matter and the Committee is strongly of the opinion that it should no longer be considered a duty of this Committee.

(2) It is recommended that in the future the personnel of the Committee on Co-operation be selected so as to include one representative from each of the Divisions of the Society and that so far as possible the number of members on the Committee be limited to 10. At the present time there are 12 members and it seems to the Committee that this is an unnecessarily large number for the work which the Committee has to do, and it means that all communications between the chairman and the members of the Committee must be written twice in order to secure a sufficient number of clear copies. This extra labor seems unnecessary and should be avoided in the future. The correspondence of the Committee has involved the writing of something over a hundred letters during the year.

Respectfully submitted,
E. W. WASHBURN, Chairman.

Membership Committee

Your Committee on Membership begs leave to submit the following report for the year 1920:

As mentioned in last year's report, plans were already started with a view of adding a couple of Divisions to the Society and thus bring new interests into the organization.

With one of these Divisions in mind, Mr. Frederick H. Rhead was placed on the Committee and chiefly through his efforts has it been possible to advance as far as we have with the Ceramic Decorative Processes Division. We have every reason to believe this will be a success. If so, it will be the means of bringing in three hundred, or more, members.

Plans were also made for creating interest in a successful Heavy Clay Products Division, and a Division for those interested in cements, lime, mortar, etc. These plans have not developed as far as they should be. Plans for the Cement, Lime, and Mortar Division, however, have developed further than it would appear at present, and we may eventually expect a number of new members from this source.

So far, the development of the Heavy Clay Products Division has been discouraging. The field is enormous, and a great deal of missionary work has already been done for us, and we should at present have many more members interested in these products than we now have.

This failure is due, not only to the Membership Committee in neglecting to choose enthusiasts in this line, but chiefly on account of the lack of enthusiasm on the part of the officers and members of the old Brick and Tile Division. There is no reason why we should not have four or five hundred members interested in this work, provided we have made the activities of the Society such that the manufacturers could not afford to stay out.

The success of all our Divisions depends on this, and will depend on it more and more as the Society grows.

A few people join a Society because they are live wires and enthusiastic about anything in their line. A few join because they feel it is their duty. The majority, however, join for direct tangible benefit. Our Society is chiefly made up of of the first two classes, and we have reached our limit of growth unless we can interest the third class.

Two or three active Divisions are already interesting people of the third class, and will continue to grow. The peculiar thing about these Divisions is that, generally speaking,

they are not really as purely ceramic in their scope as are the less enthusiastic Divisions. The members of the Society in general, and the weaker Divisions in particular, must rise to the occasion if we are going to maintain the position in the Ceramic world that we should.

Two or three fields from which members can be secured should be mentioned at this time. Among these are the users of refractories. Some of these people have already shown considerable interest in the Society, but there are many more who should become interested. All the large power companies, steel mills, smelters, etc., are possible candidates and in most cases should be Corporation members.

A suggestion of one method of interesting these people would be a Hand Book on Refractories, compiled by the Refractories Division, and to be sold at a price sufficient to cover the expense of printing. This could be gotten up by the various experts in the Refractories Division, and would not only make interesting reading in the Journal, if part of the work was published each month, but by so doing could be prepared for distribution and sale as a Hand Book at a nominal price.

In view of the fact that the men who are most capable of writing a book of this sort are those most interested in the future market for refractories, it would mean not only increased benefit to the Ceramic Society, but also a direct benefit to the manufacturers.

The Standards Committees of the Divisions are also in a position to create interest in the Society by preparing standards for purchasers. This is particularly true of refractories, enameled iron, glass, and some type of porcelain.

Our Corporation membership is not what it should be. However, in increasing our membership, it must be borne in mind that Corporations are paying their yearly dues either because they think the Society is a good thing, and deserves encouragement and support, or else because they expect to derive some benefit from us, and want value received. We should go on the principle that all the members are of the

latter type, and we will not only sell ourselves to those who have to be sold to, but also give value received to those who are helping us.

The Division Chairmen can accomplish a great deal along this line by making it possible for the Divisions to be represented at gatherings, particularly of business men interested in their branches. For example, at meetings of the Refractories Association, The American Terra Cotta Society, The U. S. Potters' Association, The Tile Association, etc., there are nearly always members of the Ceramic Society present, but they do not go as members of the Society to boost for the Society. These are the places where a boost for the Society counts, and where we can really do good.

The Chairman's office has sent out the following correspondence during the year:

March—Form Letter	1300 letters
December—Form Letter	1350 letters
December—Resolution Card	1400 cards
February—Corporation Membership List	1400 letters
General—Personal Letter to each delinquent	142 letters
Total	5592

Besides this, there were a great many personal letters to various members of the Society, and prospects; also 600 letters sent out about February 13th, to various prospects for the Heavy Clay Products Division.

The fact that it was necessary to send out 142 personal letters to delinquent members as late in the year as August should furnish food for thought. Our records show that 42 acknowledged receipt of these letters, and I think Professor Binns also received some response.

This number of delinquents last year, together with the increase in dues for Associate members, and the general business condition this year, means that we must not only be sure we have something to sell prospective members this year, but work hard to sell it.

Professor Binns and Miss Binns deserve much credit for the assistance they have given the Membership Committee, and I wish to express my thanks to them.

It is difficult to estimate the amount of work done by the Membership Committee, or the Society as a whole. The one thing that will make a membership campaign a success is the belief on the part of each member of the Society that he is an important member of the Membership Committee, and that it is his duty to boost the interests of the Society, provided, of course, that he believes in it. It is the duty of the officers, and the various branches to make the Society such that the members can not help but believe in it.

The future is going to be largely dependent upon the Ceramic Society members and their ability to maintain such high standards in their various branches of the profession that no branch of the profession will feel that it can undertake research or development work without the advice and council of the Ceramic Society. The fact that we have members whose advice is sought is not enough. In this case the Society is strengthened by the members. To be a real success, and function properly, the Society must be such that the members, no matter who they may be, will be strengthened because they are members.

Our Committee on Research and Development should be so organized that it can go to various Associations that have problems of a ceramic nature, and show them how research work can be undertaken by them, and result in direct gain to the members of these Associations. Those to approach in cases of this sort should be the business heads and executives of large manufacturing concerns.

The appropriations and backing that Associations of this sort would give for the right sort of advice are such that the Ceramic Society could afford to permanently employ a full time consulting engineer of high calibre to act for it.

It is not altogether within the province of the Membership Committee to say what other standing Committees shall do, but the success of the Membership Committee's

efforts is going to be governed entirely upon what they have to sell to prospective members.

A membership campaign of any sort will be a failure if people join in a moment of enthusiasm, and later find they joined a Society because they thought it meant more to them than it really did. We must make our Society such that new members will find that the older they become, the more good they are deriving from their association.

The competition we are having from several Societies, each one of which is interested in at least one of the branches of the ceramic field, is such that we cannot afford to neglect the opportunity we have now, as it is only a question of time until others will have what we have already neglected too long.

If our Society can become so strong that it will be the only organization thought of when ceramic problems are mentioned, then we can feel that we are functioning as we should.

The Chairman of the Committee wishes to take this occasion to thank the members of the Committee for their work and co-operation; also, his Secretary, Miss Grace Wohlfelder.

Respectfully submitted,

F. H. RIDDLE, Chairman.

Committee on Papers and Programs

The work of this committee during the past year has been confined largely to arranging for the program of the annual meeting. The Divisional programs being in the hands of the Division secretaries this committee could plan only in a general way, and do what was necessary in assisting the various groups.

As the symposium on kilns last year proved of such great interest it was planned to have another session this year and to include one on the problems of saggers. It is believed that this plan should be followed each year in order to get information upon specific problems that are of general interest, and especially to bring out discussion.

In addition to the usual request sent to all members, many individual letters have been written in the work of building up a balanced program. The result has not been entirely satisfactory, and probably never will be, but evidence of the work accomplished is found in the program which is offered.

It is becoming increasingly difficult to get contributions along the line of new investigations and research work. This is due largely to the reduced output of our Federal Bureaus. Although private companies are doing more research work many are disinclined to publish the results.

In many ways it would seem that it would be better if our programs presented fewer papers and more discussion. By holding our meetings in smaller groups, which allows ample time, it is believed that there should be an endeavor to bring out more discussion of special problems. In this way there can be introduced a closer co-operation between the technical men and the practical men, and between them and the manufacturer.

In addition to our recommendations of previous years our chief recommendation to the succeeding committee is that they, soon after the annual meeting, send cards to all members asking that they indicate what work they will undertake during the year. By this means it will be possible for the chairman of this committee to keep in touch with the whole field, and to plan in such a way that the program of the annual meeting will represent a widely diversified list of contributions sure to be of interest and value to all members.

Your committee would further recommend that in the arrangement of the program all papers which seem to fall in more than one classification be included in the program of each division in which they might be of interest. It would be necessary that papers be so arranged as to time that they would not conflict. There has been considerable complaint that it is often not possible to hear certain papers because they appear only in one division and that members cannot always keep in touch with the various papers in which they are interested.

We would also suggest that the succeeding committee consider the advisability of including all papers of general interest in the general program. This may necessitate extending the meeting to five days so as to give an extra day to the general program.

Respectfully submitted,
R. H. MINTON, Chairman.

Committee on Publications

The receipts and expenditures for the year, together with those for preceding years, are given below:

Receipts

	Vol. I (1918)	Vol. II (1919)	Vol. III (1920)
From advertisers	$3,902.40	$4,678.24	$5,259.00
Bills receivable	....	372.00	1,430.00
From non-member subscriptions	486.00	720.00	1,312.01
Total	$4,388.40	$5,770.24	$8,001.01

Disbursements

	Vol. I (1918)	Vol. II (1919)	Vol. III (1920)
Printing and distributing	$4,283.00	$5,737.23	$7,564.88
Abstracts	....	358.90	569.77
Reprints	....	431.45	461.80
Salaries (editor and assistant)	1,733.33	1,953.33	2,129.91
Editor's office expense	123.33	353.87	166.52
Total	$6,139.66	$8,834.78	$10,892.88
Excess of expenditures over Journal Revenue	$1,751.26	$3,064.54	$2.891.87

The Journal should be made self-supporting and the following steps were taken during the year to increase the revenue.

1. The rates for advertising were substantially increased, effective for new advertisers December 1, 1920, and applicable to all advertisers on June 1, 1921. The new rates established are shown in the following schedule.

ADVERTISING RATES

Space	*One Insertion*	*Three Insertions*	*Six Insertions*	*Twelve Insertions*
Eighth page	$ 9.75	$ 9.00	$ 8.25	$ 7.50
Quarter page	18.00	16.50	15.00	13.50
Half page	33.00	30.00	27.00	24.00
Full page	60.00	54.00	48.00	40.00

Preferred space: Back cover........................List plus 25%
Inside back cover....................List plus 20%
Opposite inside back cover..........List plus 20%
First page after reading............List plus 20%

2. An agreement has been made with L. W. Allison, of Newark, N. J., to solicit advertising upon a commission basis.

3. The price of the Journal to non-member subscribers has been increased from \$6.00 to \$8.00 per year.

By these means it is hoped to bring the Journal revenue up to the desired point, that is, equal to or above the expenses of publication.

There has been ample subject matter for each number of the Journal and early difficulties in this direction have largely disappeared.

Regularity of issue has not yet been secured but improvement has been made and the Journal can be now counted upon to appear at least during the scheduled month.

The number of copies to be printed has been increased from 2200 to 2500 monthly.

Editor Staley found it necessary to resign towards the close of the year, having edited Volume III, and E. W. Washburn was appointed editor to take charge beginning with the January, 1921, number, (Vol. IV, No. 1).

Respectfully submitted,
L. E. BARRINGER, Chairman.

Committee on Rules

This Committee has had a number of important matters assigned to it during the past year and begs to report as follows concerning its activities:

During April, 1920, the modification of the Rules of the Society as regards Industrial Divisions was considered and recommendations submitted to the Board of Trustees.

During June, 1920, this Committee considered further changes in Rules governing Divisions and also changes in the Rule governing the Appointment of the Committee on Standards, and recommendations submitted to the Board of Trustees.

During July, 1920, this Committee considered the change of Rules governing Initiation Fees for Associates and Annual Dues for Active and Associate Members. Its recommendation was submitted to the Board of Trustees.

During October and November this Committee developed, with the aid of several other members of the Society, a set of By-Laws for the government of Technical Divisions of the Society and these were approved by the Board of Trustees in December, 1920.

This Committee has also been busy on a very extensive revision of the Rules of the Society, by which these will be changed to a Constitution and By-Laws.

This has consumed much time and is still undergoing modification but will be submitted to the Board of Trustees at this meeting.

Respectfully submitted,

ARTHUR S. WATTS, Chairman.

Committee on Sections and Divisions

The past year has witnessed a further extension of the scope of the internal as well as the external activities of the Society. Through the Student and Local Sections the work of the Society is being actively carried on by frequent meetings throughout the year in the larger ceramic centres, and the Industrial Divisions are providing a means for closer cooperation in the study of problems common to various groups of members engaged in the same branch of industry.

Owing to the lack of a definite rule on the subject, some of the Industrial Divisions were extending the privilege of membership in the Division to persons who were not members of

the parent society. It was the opinion of your committee that such procedure was not consistent with the aims and objects which it had in view in the formation of Divisions and felt that the word "Divisions" should be construed as the term used to designate a classified group of the society in contrast to a separate and distinct organization within the society designated by the term "Section." All non-members who were allowed to retain their membership in the Division through a special ruling designated to prevent antagonism should be urged to become members of the society so that the organization of the Division can proceed strictly according to the recently adopted rules of the society pertaining thereto.

A proposal was received to form a Division which would embrace those members who were directly interested or engaged in the artistic and decorative branches of the Ceramic Industry. After a survey of the number of members who would actively participate in such a Division it seemed that there was sufficient enthusiasm to warrant the formation of a "Division on Ceramic Decorative Processes." The temporary organization of this group has already been completed and the permanent organization should be effected at this meeting. We believe that the name which this Division is now designated by is far too cumbersome and at the same time not wholly descriptive of the branches of industry embraced.

During the past year all of the Divisions with the possible exception of the Whitewares and Brick and Tile have been functioning properly and making as rapid progress as could be expected in the short time they have been in existence. There is still much to be done to strengthen the position and broaden the scope of activities of all the Industrial Divisions and with the reorganization of the two previously mentioned Divisions it is to be hoped that the coming year will see each carrying its share of the work of the society.

Most of the Local Sections are holding regular meetings at stated intervals and are a credit to the Society. However, there are one or two Sections which exist in name only. This is due chiefly to the fact that although the number of persons interested is larger than in some other sections, the territory

embraced in the Sections is so large that it is impossible to hold a meeting at any point which can be reached by an even moderate amount of travel on the part of those interested.

We would recommend that due consideration be given to the abolishment of the present Sections on geographical lines and the re-establishment of Local Sections in cities or small areas of intensive ceramic activity. Furthermore we believe that the initiative for the formation of the Sections should emanate from those who will eventually become the members of such a Section and that Sections be established only after a careful survey of the number of active members of a locality who are willing to pledge their services to the upbuilding and continuation of such a Section.

The potential possibilities of future development and extension of the activities of the Society through its Sections and Divisions are very great and should not be lost sight of by the incoming committee.

Respectfully submitted,

S. C. LINBARGER, Chairman.

Summer Meeting, 1920

The 1920 annual Summer Meeting was held in Chicago, August 16, 17 and 18. Headquarters were established at the Hotel La Salle, and a total of 113 members registered. This established a new record for attendance at Summer Meetings.

On Monday the party visited the plant of the Bach Brick Company, where the use of the Penfield setter and the combination fuel oil-steam system of burning common brick proved highly interesting. Later in the afternoon the plant of the Northwestern Terra Cotta Company was visited. Here the Dressler Tunnel Kiln, completed and ready for operation and the new humidity dryers, successfully operating, held the special attention of the party for the remainder of the day.

In the evening, through the generous aid of the local manufacturers, a complimentary dinner was tendered the visit-

ing members at Hotel LaSalle. The dinner was followed by a short business session after which "Dean" W. D. Gates became Master of Ceremonies and conducted that office in his usual interesting style. R. H. Minton, President, who had just returned from an extensive trip abroad, gave us a highly interesting talk on industrial and political conditions in Germany. One or two other short informal talks and a few vaudeville stunts completed the evening's entertainment.

On Tuesday morning the party visited the plants of the Lindsay Light Company, manufacturers of gas mantels, and the Coonley Manufacturing Company, makers of enameled cooking utensils. Leaving the latter plant at noon the party was taken to the plant of the Western Electric Company, where a most excellent complimentary luncheon was served. The entire afternoon was spent witnessing the various operations employed in the manufacture of equipment used in the telephone and telegraph industry.

The final day of the meeting started with a pleasant ride on a special train on the North Shore Electric R. R., through the beautiful north shore suburbs of Chicago, passing Ft. Sheridan and the Great Lakes Naval Training Station to Waukegan and North Chicago. The first plant visited here was that of the American Steel & Wire Company, where the rolling and drawing of 6" billets into wire and the subsequent manufacture of springs, fencing, etc., was watched with great interest. We then visited the plant of the Chicago Hardware Foundry Company, manufacturers of porcelain enamel ware, and were again tendered a complimentary luncheon by this company.

This closed the formal part of the program. However, several of the members stopped off at Ravinia Park for an enjoyable evening of Grand Opera.

The sustained interest on the part of visiting members and cheerful adherence to the program as mapped out, made the work of the Local Committee a real pleasure.

Respectfully submitted,

F. B. ORTMAN, Chairman.

Committee on Standards

The work accomplished during the past year by this Committee has not been large in volume because it has been concerned largely with the details of putting methods into final form for publication. During the first six months of the period the whole membership was especially active. The later slacking off in the Committee's activity was due almost entirely to the fact that the Chairman was not able to give to the work the increased amount of time that became necessary.

At present we have nearly completed the work outlined as in progress in our last year's report. The membership of the Society by letter ballot have adopted as standard the methods for Drying shrinkage, Shrinkage and Pore Water, Water of Plasticity, True Specific Gravity, Softening Point, and Behavior in Firing. It was gratifying to the Committee that in every case where a negative ballot passed, the member took the time to present his reasons for so doing. The tentative and optional methods have been completed and there remains to be done only the final arrangement of the appendix in order to have all this work ready for the printer.

It would be advisable to have this in print at as early a date as possible for the very limited editions to the two former bulletins have become exhausted and continued requests are still being made for them. In this connection, we would recommend that you give some thought to the advisability of making a nominal charge in the future to cover the cost of printing and distributing the report of this Committee. Almost invariably those requesting copies inquire as to the price. This policy has already been adopted with respect to the report of the Committee on Ceramic Raw Materials. Considering the fact that the Society's income from dues is hardly sufficient to meet operating costs, a nominal charge for special publications would seem entirely in order.

As mentioned last year the Committee has considered a change in the rule governing the appointment and functions of the Committee on Standards so that it may better represent the varied activities of the Society and serve also to correlate

any standardization work done within the several divisions, this resulting in our presenting to the Board and the Committee on Rules a revision of the rule pertaining to the appointment and duties of the Committee on Standards. This was later submitted by the Committee on Rules through the Board to the membership and was accepted by letter ballot.

The Committee for 1921 will be appointed on this basis and it is expected that this new arrangement will make possible more thorough and efficient work on standardization of methods than has been possible in the past.

Respectfully submitted,

M. F. BEECHER, Chairman.

Committee on Ceramic Research

(Joint Committee with the National Research Council)

The committee held two meetings during the year 1920, both at Washington, D. C. At the meeting held in May the appointment of a research fellow at the Corning Glass Works, Corning, N. Y., on the subject of the viscosity of glasses at elevated temperatures was reported to the council at large and approved. This work is being done at the University of Illinois. Plans were also discussed at the first meeting for the promotion of technical research in the ceramic industry. It was proposed to approach the glass and clay pot industry on the subject of an investigation dealing with the subject of American clays and the compounding of mixtures, suitable for resisting the attack of the more corrosive glasses. It was further proposed to approach the pottery industries in connection with an investigation, having for its purpose the correlation of the thermal expansion of the bodies and glazes with their compositions. Both of these projects were communicated to the industries concerned, but so far with negative results. A general study of the properties of clays was discussed, but the industries chiefly concerned have not yet been approached, though it is felt that a general investigation of the physical properties of clays is urgently needed. Although

considerable work has been done in connection with this broad topic no systematic correlation has been attempted and no serious effort has as yet been made to study the characteristics of clays from the more exact physical standpoint.

During the summer the subject of a co-operative investigation relating to the structural clay products was discussed with Mr. E. R. Sturtevant at his invitation. The feasibility of conducting such a project was pointed out at this conference and the desirability of bringing together the various heavy clay products interests shown. This matter was in abeyance until a meeting was held in Cleveland on Dec. 20th, 1920, attended by the secretaries of the Hollow Building Tile, the Common Brick, Face Brick, and Paving Brick Associations. At this meeting a possible organization for purposes of co-operative research was discussed and the secretaries agreed to submit the matter to their organizations. This was done and another meeting was held in Chicago on Feb. 15th, at which committees, appointed by five trade associations, were present. At this meeting it was proposed to submit to the associations concerned a plan of raising a fund of $10,000 for the year 1921 and at least as much for the year 1922. The proposed co-operative research is to be directed by an executive committee, composed of the chairmen of the several constituent committees. The committee is to select a permanent chairman and to elect a permanent secretary and such other officers as may be required. In addition a technical committee is to be created which is to have charge under the executive committee of the actual prosecution of the research work. The writer was chosen as chairman of the technical committee with power to appoint such other members as may be required for the conduct of the work. The chairman requested the Bureau of Standards and the Bureau of Mines to take representation on this committee and asked that the chairman of the Heavy Clay Products Division of the A. C. S. become a member of the committee, ex officio. In addition Dr. E. W. Washburn of the University of Illinois was asked to serve. It is the intention to appoint additional members of the technical staff as the work is brought on the way.

The plan as outlined is to be submitted to the several associations for final approval and a meeting of the executive committee is to be held as soon as a research program has been worked out by the technical committee. A permanent organization will then be formed and the program submitted passed upon.

The members of the technical committee, composed of representatives of the Federal Bureaus and the Research Council, met at the convention of the A. C. S. in Columbus, O., and outlined a tentative program embracing subjects related to the burning of clay products. This outline is to be enlarged and worked out in detail for discussion and approval at a subsequent meeting.

Respectfully submitted,

A. V. BLEININGER, Chairman.

PUBLICATIONS OF THE AMERICAN CERAMIC SOCIETY

Annual Transactions			Bound in Cloth
Vol. I.	1899	110 pages	$4.75
Vol. II	1900	278 pages	in complete set only
Vol. III	1901	238 pages	$4.75
Vol. IV	1902	300 pages	$5.50
Vol. V	1903	420 pages	out of print
Vol. VI	1904	278 pages	$6.50
Vol. VII	1905	454 pages	$6.50
Vol. VIII	1906	411 pages	$6.50
Vol. IX	1907	808 pages	out of print
Vol. X	1908	582 pages	in complete set only
Vol. XI	1909	632 pages	$6.50
Vol. XII	1910	882 pages	in complete set only
Vol. XIII	1911	837 pages	$6.50
Vol. XIV	1912	888 pages	in complete set only
Vol. XV	1913	747 pages	$8.00
Vol. XVI	1914	611 pages	$8.00
Vol. XVII	1915	815 pages	$8.00
Vol. XVIII	1916	947 pages	$8.00
Vol. XIX	1917	707 pages	out of print
	Journal		
Vol. I.	1918	892 pages	$6.00
Vol. II	1919	1030 pages	$6.00
Vol. III	1920	1016 pages	$6.00

A complete set of the Transactions, minus Vols. IX, XII, and XIX which are out of print, may be purchased at............ $150.00

(Second-hand copies of Vols. V, IX, and XIX, are sometimes available. Orders for these should be filed with the Secretary.)

To members of the Society a reduction of 40% will be made from the above prices. Members cannot purchase more than one copy of each volume at members' rate.

The Society has also published the following books, which will be sold net, at the prices listed, to the public and members alike:

The Collected Writings of Dr. Hermann August Seger, Volume I, (a) Treatises of a general scientific nature. (b) Essays relating to Brick and Terra Cotta, Earthenware and Stoneware, and Refractory Wares. 552 pages. Bound in cloth......$7.50

The Collected Writings of Dr. Hermann August Seger, Volume II. (a) Essays on White Ware and Porcelain. (b) Travels, Letters and Polemics. (c) Uncompleted works and extracts from the archives of the Royal Factory. 605 pages. Bound in cloth $7.50

A Bibliography of Clays and the Ceramic Arts, by Dr. John C. Branner, 1906. 451 pages. Bound in cloth. Contains 6027 titles of works on Ceramic subjects.................. $2.00

Collective Index to the Transactions of the American Ceramic Society, compiled by E. J. Crane...................... $1.50

The above publications can be obtained of the Secretary and will be shipped at the consignee's expense by express or parcels post to any address on receipt of the price. To all who purchase a complete set of the Transactions, a copy of the Branner Bibliography is given free. Make all checks or money orders payable to The American Ceramic Society.

CHARLES F. BINNS, Secretary,
Alfred, N. Y.

Libraries Where Publications of the American Ceramic Society May be Found

Boston Public Library, Boston, Mass.
Carnegie Library, Pittsburgh, Pa.
Carnegie Free Library of Allegheny, Pittsburgh, Pa.
Cincinnati Public Library, Cincinnati, Ohio.
Cleveland Public Library, Cleveland, Ohio
Columbia University Library, New York City.
Cornell University Library, Ithaca, N. Y.
John Crerar Library, Chicago, Ill.
Detroit Public Library, Detroit, Mich.
Free Library, Philadelphia, Pa.

Grosvenor Public Library, Buffalo, N. Y.
Hall of the Franklin Institute, Philadelphia, Pa.
Iowa State College Library, Ames, Iowa.
Johns Hopkins University Library, Baltimore, Md.
Library of Congress, Washington, D. C.
Los Angeles Public Library, Los Angeles, Cal.
Massachusetts Institute of Technology, Boston, Mass.
Missouri School of Mines, Rolla, Mo.
New Jersey Ceramic Research Station, New Brunswick, N. J.
Newark Free Public Library, Newark, N. J.
New York Public Library, New York City.
New York State Library, Albany, N. Y.
New York State School of Ceramics, Alfred, N. Y.
Ohio State University, Columbus, Ohio.
Princeton University Library, Princeton, N. J.
Providence Public Library, Providence, R. I.
Purdue University Library, LaFayette, Ind.
Spokane Public Library, Spokane, Wash.
Syracuse Public Library, Syracuse, N. Y.
St. Louis Mercantile Library, St. Louis, Mo.
St. Louis Public Library, St. Louis, Mo.
Trenton Free Public Library, Trenton, N. J.
United States Patent Office, Washington, D. C.
University of California, Berkeley, Cal.
University of Colorado, Boulder, Colo.
University of Illinois, Urbana, Ill.
University of Iowa, Iowa City, Iowa.
University of Michigan, Ann Arbor, Mich.
University of Minnesota, Minneapolis, Minn.
University of Texas, Austin, Texas.
University of Utah, Salt Lake City, Utah.
University of Washington, Seattle, Wash.
University of Wisconsin, Madison, Wis.
Worcester Free Public Library, Worcester, Mass.

FOREIGN

Brunswick Technical School, Brunswick, Australia.
Bureau of Science, Manila, P. I.
Chemical Society, London. England.
Library, Pall Mall, Hanley, England.
McGill University Library, Montreal, Canada.
Mudie's Select Library, London, England.
New South Wales Public Library, Sydney, Australia.
Tohoku Imperial University Library, Sendai, Japan.
University of Toronto Library, Toronto, Canada.
Victoria Library, Melbourne, Australia.

CONSTITUTION AND BY-LAWS

CONSTITUTION

ARTICLE I

(1) This Society shall be known as the American Ceramic Society.

(2) The object of the Society is to advance the ceramic arts and sciences by meetings for the reading and discussion of papers, the publication of scientific literature, and other activities.

ARTICLE II

Membership

(1) The Society shall consist of Honorary, Active, Associate, and Corporation Members.

(2) Honorary Members must be persons of professional eminence, elected in recognition of their achievements in ceramic art or science. Their number shall not exceed ten.

(3) An Honorary Member shall be nominated by at least ten Active Members and unanimously approved by the Board of Trustees. Their nomination shall be placed before the Society at an annual meeting, and to be elected they must receive the affirmative vote of at least ninety per cent of those voting, by letter ballot, at the next succeeding annual election.

(4) Active Members must be persons competent to fill responsible positions in ceramics. Only Associate Members shall be eligible to election as Active Members and such election shall occur only in recognition of attainments or of services in the science, technology, or art of the ceramic or allied industries.

(5) The Board of Trustees shall at each regular meeting advance to Active Membership all Associate Members whose activity in the Society or whose prominence in the ceramic industries, in the opinion of a majority of the Board of Trustees, merits such recognition. Any Active Member may nominate in writing Associates for Active Membership, accompanying same by a written statement of the qualifications of each candidate, and the Board of Trustees shall act on such recommendations at the next regular meeting of the Society.

(6) Associate Members must be persons interested in the ceramic or allied industries.

(7) Corporation Members must be persons, firms, or corporations who, being interested in the Society, make such financial contributions for its support as are prescribed in Article III. Their membership shall become operative on payment of dues as prescribed in Article III.

(8) All Honorary Members, Active Members, Associate Members, and Corporation Members shall be equally entitled to the privileges of membership, except that only Active Members and one representative of each Corporation Member shall be entitled to vote. Such representative shall be officially designated by the person, firm, or corporation represented. Only Active Members shall be entitled to hold office. The roster of each grade of membership shall be printed separately in at least one publication issued by the Society annually.

(9) Any person may be expelled from any grade of the membership of the Society if charges signed by five or more Active Members be filed against him or her, and if the Board of Trustees examine into and sustain said charges by a majority vote. Such person, however, shall be first notified of the charges against him and be given a reasonable time to appear before the Board of Trustees or to present a written defense, before final action is taken.

ARTICLE III

Dues

(1) Honorary Members shall be exempt from all fees and dues.

(2) The annual dues for Active and Associate Members shall be fixed by the Board of Trustees but shall not exceed ten dollars, six dollars of which shall be a subscription to the **Journal of the American Ceramic Society.**

(3) Corporation Members shall pay such annual dues as are fixed by the Board of Trustees but these shall not be less than twenty-five dollars, six dollars of which shall be a subscription to the **Journal of the American Ceramic Society.** The privileges of membership shall begin upon payment of the annual dues.

ARTICLE IV

Officers

(1) The affairs of the Society shall be managed by a Board of Trustees consisting of the President, the Vice-President, the Treasurer, the retiring President, his immediate predecessor, and three Trustees. The President, the Vice-President, and the Treas-

urer shall be elected to serve one year. The Trustees shall be elected to serve three years, one Trustee being elected each year.

(2) The President shall have general supervision of the affairs of the Society under the direction of the Board of Trustees and shall perform such other duties as pertain to his office.

(3) He shall countersign the checks drawn by the Treasurer when such drafts are known by him to be proper and duly authorized by the Board of Trustees.

(4) A Secretary shall be appointed by the Board of Trustees for a term of not more than 2 years.

(5) The Secretary shall see that all moneys due the Society are carefully collected and transferred to the custody of the Treasurer. He shall carefully scrutinize all expenditures and use his best endeavors to secure economy in the administration of the Society. He shall personally investigate and certify the accuracy of all bills or vouchers on which money is to be paid. He shall have charge of the books of accounts of the Society and shall furnish monthly to the Board of Trustees a statement of monthly balances. He shall present annually to the Board of Trustees a balance sheet of his books as of the 31st of December and shall furnish from time to time such other statements as may be required of him.

(6) He shall conduct the correspondence of the Society and keep full record of the same. He shall transmit promptly to the Board of Trustees for their consideration all communications not of routine nature. He shall cause to be published in the Journal the results of all balloting on the business of the Society unless otherwise ordered by the Board of Trustees. He shall perform all other duties which may from time to time be assigned to him by the Board of Trustees.

(7) The Secretary may be paid a salary to be determined by the Board of Trustees.

(8) The Secretary shall furnish a suitable bond for the satisfactory performance of his duties, which shall be held in the custody of the President.

(9) The Treasurer shall receive all moneys due the Society and deposit the same in the name of the Society in a National Bank designated by the Treasurer and approved by the Board of Trustees. He shall invest all funds not needed for current disbursements, as shall be ordered by the Board of Trustees. He shall pay all bills by draft, when certified by the Secretary or as ordered by the Board of Trustees. He shall furnish a satisfactory

bond for the proper performance of his duties, which shall be held in the custody of the President.

(10) All securities belonging to the Society shall be held in the custody of the Treasurer.

(11) The accounts of the Secretary and of the Treasurer shall be audited before each annual meeting by a certified public accountant or some other competent person designated by the Board of Trustees.

(12) A vacancy in any office shall be filled by appointment by the Board of Trustees but the new incumbent shall not thereby be rendered ineligible for re-election to the same office at the next annual meeting. On the failure of any officer or any member of a committee to execute his duties within a reasonable time, the Board of Trustees, after duly warning such person, may declare the office vacant and appoint a new incumbent.

(13) A majority of the Board of Trustees shall constitute a quorum, but the Board of Trustees shall be permitted to carry on such business as they may desire by letter.

ARTICLE V

Elections

The nominating committee shall be composed of the last two ex-presidents and one representative elected by each Division and Local Section who shall select a ticket for the offices of President, Vice-President, Treasurer, and one Trustee. The Secretary of the Society shall be chairman (without vote.) At least ninety days before the annual meeting the Secretary shall send the names of the nominees to each voting member. Any ten members, at least five of whom shall be Active, may constitute a self-appointed nominating committee and present the names of any nominees to the Secretary, provided this is done at least thirty days before the annual meeting. The names of all nominees, provided their assent has been obtained before nomination, shall be placed upon the ballot in alphabetical order and shall be mailed to each voting member, not in arrears, at least twenty days before the annual meeting. The voting shall be confined to the names appearing on this ballot. The ballot shall be enclosed in an envelope on which there shall be no mark of identification other than the word "Ballot." This envelope shall be enclosed in another envelope for mailing, addressed to the Secretary, upon the back of which the voter shall endorse his name. The envelopes and ballots shall be opened in the presence of three scrutineers appointed by the President, who will report the result of the election at the last session of the annual meeting. A plurality of affirmative votes cast shall elect.

ARTICLE VI

Standing Committees

(1) The following Standing Committees shall be appointed annually by the Board of Trustees:

1. Rules
2. Publications
3. Membership
4. Standards
5. Sections and Divisions
6. Papers and Programs
7. Co-operation
8. Research and Development

The chairman of each committee shall be appointed by the Board of Trustees.

(2) The Committee on Rules shall consist of five members in addition to the chairmen of the Rules Committees of the divisions having such committees. It shall receive all recommendations relating to changes of Constitution and By-Laws and shall report upon the same to the Secretary for transmission to the Society. It shall have power to propose changes in the Rules of the Society.

(3) The Committee on Publications shall consist of the Editor and four members. The duties of the Editor and Committee on Publications are defined under Article X on Publications.

(4) The Committee on Membership shall consist of at least five members in addition to the chairmen of Membership Committees of the divisions having such committees, and shall have power to appoint sub-committees. Its function shall be to undertake systematically the enlargement of the membership of the Society amongst those interested in the ceramic and allied industries.

(5) The Committee on Standards shall consist of at least five members in addition to the chairmen of the Standardization Committees of the Divisions having such committees, and it shall have power to appoint sub-committees.

(6) The divisional Standardization Committees shall be appointed in and by their respective divisions. Their function shall be the preparation of tests and specifications for the materials and products of their respective branches of the ceramic industry. Each shall be responsible to its own division, but all reports, resolutions, or recommendations that are to be printed or generally distributed shall be approved by the Committee on Standards before publication.

(7) The function of the Committee on Standards shall be to prepare or have prepared tests and specifications for ceramic materials and products and to submit to the Board of Trustees written reports, resolutions, and recommendations relating thereto. The Committee may report at any regular meeting of the Society. For adoption, these reports, resolutions, and recommendations must be submitted in printed form to the members of the Society at least six months before a vote may be taken, during which time any amendments, changes, or corrections, suggested by any member may, with the approval of the Committee, be incorporated. The reports, resolutions, and recommendations as amended shall then be submitted by letter ballot to the voting members. A two-thirds vote shall be required for adoption, and the polls shall close 60 days after distribution of the ballot.

(8) The Committee on Sections and Divisions shall consist of five members in addition to the chairmen of the Divisions. Its duties shall be to promote the organization and welfare of Local Sections, Student Branches, and Divisions.

(9) The Committee on Papers and Programs shall consist of the secretaries of the Divisions, the Secretary of the Society, and such other persons as the Board of Trustees may deem advisable. Its duties shall be to procure papers and discussions for the meetings and publications of the Society. The Committee may require an abstract of any paper submitted before placing it upon a program.

(10) The Committee on Co-operation shall consist of five members in addition to the chairmen of the Co-operation Committees of the Divisions having such committees.

(11) The Committee on Research and Development shall consist of five members in addition to the chairmen of the Research and Development Committees of the divisions having such committees. Its duties shall be to organize and encourage scientific investigations pertaining to the ceramic and related industries, especially those investigations which will stimulate the development of our national industries and resources. It shall be empowered to co-operate with similar committees of other scientific societies and with Government bureaus.

ARTICLE VII

Divisions

(1) Groups to be known as Divisions of the Society and to be organized from members of the Society may be authorized by the Board of Trustees for stimulating the growth and development of the Society, when such action shall seem wise and expedient. Only

bona fide members of the Society are entitled to affiliate with and participate in the activities of such Divisions, but Divisions which, prior to August, 1920, have enrolled persons who are not members of the Society, may retain such persons as members of the Division. A member of the Society may enroll in any Division in which he is interested.

(2) The affairs of a Division shall be managed by a Chairman, a Secretary-Treasurer, and such other officers as the division may deem necessary. The officers of the Division shall be elected annually by ballot at the last session of the Division held during the annual meeting of the Society and shall take office at the close of the meeting at which they are elected. All members of a Division are entitled to vote. The officers shall hold office for one year or until their successors are elected.

ARTICLE VIII

Local Sections

(1) Local Sections, each carrying some distinguishing title prefixed to the words "Section of the American Ceramic Society," may be authorized by the Society.

(2) The purposes of such sections shall be to strengthen and extend the work of the Society, as defined in Section I of its Rules, by more frequent meetings in local centers than are possible to the Society as a whole, and by bringing the benefits of the work to persons who would not otherwise be reached.

(3) Application for permission to form a Local Section must be in writing and signed by not less than ten members of the Society in good standing, residing in the general locality where the Section is to be formed, of whom one at least shall be an Active Member. To be considered at any given meeting an application must be filed with the Secretary at least thirty days prior to the date of the meeting and notice that the application is pending must appear in the program of the meeting. To be granted, the application must receive the affirmative vote of two-thirds of those present. In event of affirmative action the Society will issue a charter to the applicants, authorizing them to form a Section under the name proposed. Charters for Local Sections may be temporarily suspended by the Board of Trustees for cause, but no charter can be permanently rescinded except by vote of two-thirds of those present at a regular meeting of the Society, after due publication in the program of the meeting that the matter is pending.

(4) Local Sections shall have power to make their own rules and by-laws except that they shall not pass any rule or by-law which is in conflict with the Rules of the Society.

(5) The officers of Local Sections shall be a Chairman, a Secretary, a Councilor, and such others as the Sections may prescribe. The duties of the Chairman and Secretary shall be such as usually pertain to those offices. The Councilor shall be an Active Member of the Society. He shall be elected by the Local Section and it shall be his duty to advise the Section in all matters pertaining to its relations with the Society and to make an annual report to the Society regarding the work and status of the Section. The names of the Chairman, Secretary, and Councilor of each Section shall appear in the roster of the Society.

ARTICLE IX

Student Branches

(1) Student Branches, each carrying some distinguishing title prefixed to the words "Student Branch of the American Ceramic Society," may be established in institutions in which regular courses of instruction in ceramics are maintained.

(2) The purpose of such Student Branches shall be to strengthen and extend the work of the Society, as defined in Section I of the Rules, by enlisting the interest and support of students in ceramics while still in school and by stimulating the spirit of ceramic research among them.

(3) Application to form a Student Branch in any institution must be in writing, signed by not less than five regularly enrolled students in good standing and endorsed by two or more members of the Society. The application must be filed and acted upon as provided for Local Sections in Section IX, and may be suspended or revoked for cause in the same manner.

(4) Student Branches shall have power to make their own rules and by-laws, except that they shall not pass any rule or by-law in conflict with the Rules of the Society.

(5) The officers of Student Branches shall be a Chairman, a Secretary, a Councilor, and such others as the Student Branch may prescribe. The Chairman and Secretary shall be elected by the Student Branch and their duties shall be such as usually pertain to those offices. The Councilor shall be an Active Member of the Society, appointed by the Board of Trustees to act in this capacity to the Student Branch. The duties of the Councilor shall be to advise the Student Branch in all matters pertaining to its relations to the Society and to make an annual report to the Society regarding the work and status of the Student Branch. The names of the Chairman, Secretary, and Councilor of each Student Branch shall appear in the roster of the Society.

ARTICLE X

Publications

(1) The Board of Trustees may employ, at a suitable compensation. an editor of the publications of the Society.

(2) The Committee on Publications shall have general supervision of the publications of the Society and of contracts and expenditures connected therewith, subject to the approval of the Board of Trustees.

(3) In the consideration of papers offered for presentation or publication those papers containing matter readily found elsewhere, those specially advocating personal interests, those carelessly prepared or controverting established facts, and those purely speculative or foreign to the purpose of the Society shall be rejected. The Committee on Publications shall determine which papers shall be printed. The Committee may return a paper to the writer for correction and emendation and may call to its aid one or more members of special experience relating to the subject treated, either to advise on the paper or to discuss it.

(4) All papers and discussions presented before the general session of the Society shall become the property of the Society and their publication or other disposition shall be in the hands of the Committee on Publications.

No paper or discussion presented before a Division or Local Section shall be offered for publication elsewhere until the Committee on Publications shall have had the option of accepting the same for use in the **Journal of the American Ceramic Society.**

(5) The Committee on Publications shall provide for the publication of a monthly periodical entitled the **Journal of the American Ceramic Society**, the subscription price of which shall be six dollars to members and eight dollars to non-members.

(6) One copy of each issue of the paper-bound edition of the Journal shall be sent prepaid to each member of the Society not in arrears. No member shall be furnished with more than one copy of each issue free for any single year. A member may be permitted to complete by purchase one file of the publications of the Society at less than the current commercial rate, the amount to be fixed by the Board of Trustees and to be called the member's rate.

(7) The Secretary shall have the custody of all publications of the Society, shall keep them safely stored and insured, and shall sell them to the public at prices which shall be fixed by the Board of Trustees. The Board of Trustees shall also, from time to time, fix the price of the volumes remaining unsold and shall have authority to refuse to sell the back volumes of the Transactions and

Journals except in complete sets, at such time as the quantity remaining of any number becomes so small as in their judgment to warrant such action.

(8) The Editor shall request the author of each article appearing in the Journal of the Society to fill out and sign, within a definite time limit, a form, specifying the number of reprints of said article, if any, which he desires. This form shall contain a table from which can be computed the approximate cost at which any reprints will be furnished. In event that the expense of furnishing the desired number of reprints is large, the Board of Trustees may require the author to pay part or all of the cost involved before the publication of the reprints is begun. On receipt of such signed order within the time limit set the Editor shall cause to have printed the desired number of copies. If the author makes no reply or replies after the time limit has expired then the Society will not be responsible for the publication of any reprints of the article in question except at the usual market price for the printing of new matter.

(9) No one shall have the right to demand the publication of an article independent of the discussion which accompanied it and no one having taken part in a discussion upon an article shall be entitled to order reprints of the discussion separately and apart from the article itself.

(10) The Society is not, as a body, responsible for the statement of facts or opinions expressed by individuals in its publications.

ARTICLE XI

Parliamentary Standard

Roberts' "Rules of Order" shall be the parliamentary standard on all points not covered by these rules.

ARTICLE XII

Amendments

Any proposed amendment to this Constitution must be presented in writing at a regular meeting of the Society and, if approved by the Committee on Rules or by any ten Active Members, must be printed on a ballot and sent out not earlier than thirty nor later than sixty days after the adjournment of the meeting at which the amendment was presented. If the said letter ballot shows an affirmative vote of not less than two-thirds of the total vote cast within fourteen days of the date of mailing, then the same shall be declared carried and shall at once become effective.

ARTICLE XIII

By-Laws

The Society shall make such By-Laws not in conflict with this Constitution as may be necessary for the proper government of the Society. Such By-Laws shall become operative when approved by the Board of Trustees and confirmed by a two-thirds affirmative vote of the members voting at any annual meeting.

BY-LAWS

SECTION I

Meetings

(1) The annual meeting shall take place on the first Monday in February, or as soon thereafter as can be arranged, at such place as the Board of Trustees may decide, at which time reports shall be made by the Board of Trustees, Treasurer, and scrutineers of election, and the accounts of the Treasurer shall be audited by a committee of three appointed by the President. Twenty-five Active Members shall constitute a quorum at any regular meeting and a majority shall rule unless otherwise specified.

(2) Other meetings may be held at such times and places during the year as the Board of Trustees may decide, but at least twenty days notice shall be given of any meeting.

(3) The President shall appoint at the annual meeting a committee of five, to be known as the Summer Meeting Committee, whose duty it shall be to arrange for a summer excursion meeting at some suitable point. They shall then select a local committee which shall have charge of the details of the meeting. The expenses of the Summer Meeting Committee in arranging the program of visits and for printing, rooms, and facilities for meetings shall be borne by the Society.

SECTION II

(1) At the Annual Meeting of the Society, the order of business shall be as follows:

1. President's address.
2. Reading of minutes of last meeting.
3. Reports of the Board of Trustees and Treasurer.
4. Old business.
5. New business.
6. Reading of papers.
7. Announcement of election of officers, Honorary and Active Members.
8. Installation of officers.
9. Appointment of committees.
10. Adjournment.

SECTION III

Only Active Members shall be eligible to election as officers.

SECTION IV

Any members in arrears for over one year may be suspended from membership by the Board of Trustees until such arrears are paid. Active Members in arrears are not eligible to vote. The annual dues of Active and Associate Members are payable on January first.

SECTION V

The Secretary of each Division, Local Section, and Student Branch shall report to the Secretary of the Society the names of its officers and Standing Committee Chairmen within three weeks of their election or appointment and shall also furnish the Secretary with a complete list of its membership on April 1st of each year.

SECTION VI

(1) Any person interested in the ceramic and allied industries is eligible to membership in a Local Section.

(2) Local Sections shall have power to fix their own dues or assessments, such dues or assessments being in addition to and independent of the regular dues and assessments of the Society upon its members. No Section shall have authority to incur debt in the name of the Society or for which the Society may become liable.

SECTION VII

(1) Membership in a Student Branch shall be limited to the instructional force and regularly enrolled students of schools in which branches are located, subject to the rules of the school concerned governing outside activities of students.

(2) Student Branches shall have power to fix their own dues and assessments and, as such, shall pay no dues to the Society. No Student Branch shall have authority to incur debt in the name of the Society or for which the Society may become liable.

(3) Members of a Student Branch as such shall pay no dues to the Society but upon depositing a certificate of good standing from their Secretary, may purchase from the Society its publications at the same rate as Associate Members of the Society. This privilege shall cease when the student's connection with the school ceases, but members of a Student Branch, upon leaving school, may at once become Associate Members of the Society by depositing their certificates, making proper application, and paying the regular dues.

SECTION VII

(1) The Committee on Publications shall acknowledge to the author acceptance of all contributions submitted to it and in case of rejected contributions the original copy shall be returned to the author.

(2) Contributions remaining in possession of the Committee on Publications for more than one year without publication shall cease to be the property of the Society and shall revert to the author.

SECTION VIII

The Board of Trustees shall have power to make any rules not inconsistent with the Constitution and By-Laws for the conduct of its business.

IN MEMORIAM

Robert T. Hall

Jacob Hasslacher

W. G. Hipp

J. M. McClave

Ernest Mayer

James Moses

Henry Schmidt

ALPHABETICAL LIST OF MEMBERS

Resident Active Members

Allen, F. B., Woodbridge, N. J., M. D. Valentine & Bro. Co.

Applegate, D. H. Jr., 6509 N. 6th St., Philadelphia, Pa. Schwartz, Inc.

Arnold, Howard C., 4906 McPherson Ave., St. Louis, Mo.

Ashbaugh, Chas. C., East Liverpool, Ohio, Secretary and Treasurer, West End Pottery Co.

Aubrey, Arthur J., Youngstown, Ohio, Assistant General Superintendent, Bessemer Limestone Co.

Ayres, E. B., 6th St. and Tabor Rd., Philadelphia, Pa., Proctor & Schwartz, Inc.

Babcock, M. G., 241 McKee Place, Pittsburgh, Pa., Laclede-Christy Clay Products Co.

Back, Robert, Chicago, Ill., Factory Chemist, The Wahl Co.

Bacon, Raymond F., Pittsburgh, Pa., Director, Mellon Institute.

Balmert, Richard M., Box 183, Angola, N. Y., Superintendent, Lyth Tile Co.

Balz, Geo. A., Rahway, N. J., Mechanical Engineer.

Barringer, L. E., Schenectady, N. Y., Engineer of Insulations, General Electric Co.

Barton, G. E., 227 Pine St., Millville, N. J., Chief Chemist and Technical Expert, Whitall Tatum Co.

Bates, P. H., 3220 Morrison St., Chevy Chase, D. C., U. S. Bureau of Standards.

Beecher, M. F., Worcester, Mass., Research Laboratories, Norton Co.

Bell, M. L., 901 South Ave., Wilkinsburg, Pa., Ceramic Engineer, Carnegie Steel Co., Braddock, Pa.

Bellamy, Harry T., Chicago, Ill., Hawthorn Plant, Western Electric Co.

Bently, Louis L., Beaver Falls, Pa., Superintendent, Armstrong Cork Co.

Berry, C. W., St. Louis, Mo., Chemist, Laclede-Christy Clay Products Co.

Binns, Chas. F., Alfred, N. Y., Director, New York State School of Clay-Working and Ceramics.

Binns, Norah W., Alfred, N. Y., Assistant Secretary, American Ceramic Society.

Blackmer, Edward L., 2801 Hereford St., St. Louis, Mo., Blackmer & Post Pipe Co.

Blair, Marion W., Moundsville, W. Va., Manager, Suburban Brick Co.

Blair, William P., 824 B. of L. E. Bldg., Cleveland, Ohio, Secretary, National Paving Brick Manufacturers' Association.

Bleininger, A. V., Newell, W. Va., Research Department, Homer-Laughlin China Co.

Blewett, J. B., Wellsville, Ohio, McLain Fire Brick Co.

Bloomfield, Chas. A., P. O. Drawer F, Metuchen, N. J., Treasurer, Bloomfield Clay Co.

Boeck, P. A., 1736 Morgan Place, Hollywood, Los Angeles, Cal., Celite Products Co.

Bole, George A., Columbus, Ohio, Ceramic Chemist, U. S. Bureau of Mines.

Booze, M. C., Woodland St., Holden, Mass., Norton Co.

Boughey, Joseph, 584 Roosevelt Ave., Trenton, N. J., Manager, Porcelain Department, Chas. Engelhard, Inc., Newark, N. J.

Bowman, Oliver O., Trenton, N. J., Trenton Fire Clay and Porcelain Co.

Bowman, Wm. J. J., Trenton, N. J., Trenton Fire Clay and Porcelain Co.

Brewster, Robert, Chicago, Ill.

Breyer, Frank G., Palmerton, Pa., Chief of Research Department, New Jersey Zinc Co.

Brockbank, Clarence J. (address unknown).

Brown, George H., New Brunswick, N. J., Director, Department of Ceramics, Rutgers College.

Brownlee, Wm. K., Toledo, Ohio, President and General Manager, Buckeye Clay Pot Co.

Bryan, M. L., Spokane, Wash., Washington Brick Lime and S. P. Co.

Burroughs, Francis H., Trenton, N. J., Star Porcelain Co.

Burt, S. G., 2349 Ashland Ave., Cincinnati, Ohio, Rookwood Pottery.

Butterworth, Frank W., Danville, Ill., General Manager, Western Brick Co.

Campbell, A. R., Middlesex Ave., Metuchen, N. J., Federal Terra Cotta Co.

Cannan, Wm. Jr., 522 Allen St., Syracuse, N. Y., Onondaga Pottery.

Carder, Frederic R., Corning, N. Y., Steuben Glass Works.

Cermak, Frank, 116 Fourth Ave., Schenectady, N. Y., Foreman, Porcelain Works, General Electric Co.

Cheney, M. B., Briggsdale, Ohio, The Barnebey-Cheney Engineering Co., Columbus, Ohio.

Child, J. L., Findlay, Ohio, Hancock Brick and Tile Co.

Chormann, Major O. I., 81 South Fitzhugh St., Rochester, N. Y., Pfaudler Co.

Christman, C. E., Pittsburgh, Pa., President, Federal Stamping & Enameling Co.

Clare, R. L., Woodbridge, N. J., Superintendent, Federal Terra Cotta Co.

Clark, Wm. M., Cleveland, Ohio, Glass Technology Department, National Lamp Works of General Electric Co.

Claudon, Chas. F., 1120 Brent Ave., South Pasadena, Cal.

Conkling, Samuel O., Philadelphia, Pa., Superintendent, Conkling-Armstrong Terra Cotta Co.

Cook, Chas. H., Trenton, N. J., Cook Pottery Co.

Cooke, Raymond D., Terre Haute, Ind., Chemist, Columbian Enameling and Stamping Co.

Coors, H. F., Golden, Colo., Manager, Coors Porcelain Co.

CoVan, H. E., 12369 Euclid Ave., Cleveland, Ohio, The Price Electric Co.

Cowan, R. Guy, Rocky River, Cleveland, Ohio, Treasurer, "Cowan Pottery," The Cleveland Pottery & Tile Co.

Cox, Paul E., Ames, Iowa, Professor Ceramic Engineering, Ceramic Department, Iowa State College.

Crane, Chas. W., 17 Battery Place, New York City, President and Treasurer, The Barrett Co.

Creighton, E. E. F., 27 Wendell Ave., Schenectady, N. Y., Consulting Electrical Engineer, General Electric Co.

Danielson, R. R., Washington, D. C., U. S. Bureau of Standards, 143 Industrial Bldg.

Davenport, R. W., 1583 Hurlbut Ave., Detroit, Mich.

Davis, John B., D. D. S., 22 East Greenwood Ave., Lansdowne, Pa.

Day, A. L., Ph. D., Washington, D. C., Director, Geophysical Laboratory.

Dean, Charles A., 79 Twelfth Ave., Columbus, Ohio.

DeVoe, Chas. H., Old Bridge, N. J., Old Bridge Enameled Brick & Tile Co.

Dickey, Fred L., Kansas City, Mo., General Manager, W. S. Dickey Clay Mfg Co.

Dinsmore, B. B., Trenton, N. J., General Manager, Imperial Porcelain Works.

Dobbins, T. Monroe, Camden, N. J., Secretary and Treasurer, Camden Pottery Co.

Dornbach, Wm. E., 3514 Clifton Ave., Baltimore, Md., American Refractories Co.

Dunn, Frank B., Conneaut, Ohio, President and Treasurer, Dunn Wire Cut Lug Brick Co.

Duval d'Adrian, A. L., 284 South Main St., Washington, Pa.

Ebinger, D. H., Jr., 735 Linwood Ave., Columbus, Ohio, Secretary and General Manager, D. A. Ebinger Sanitary Mfg. Co.

Edgar, David R., Metuchen, N. J., Assistant General Manager, Edgar Bros. Co.

Ellerbeck, Wm. L., D. D. S., Box 917, Salt Lake City, Utah, President and Manager, Nephi Plaster Co.

Emley, Warren E., Washington, D. C., U. S. Bureau of Standards.

Eskesen, B. K., Matawan, N. J., President and General Superintendent, Matawan Tile Co.

Fackt, George P., Denver, Colo., General Manager, Denver Terra Cotta Co.

Farnham, Dwight T., 52 Vanderbilt Ave., New York City, Vice-President, C. E. Knoeppel & Co. Inc.

Fickes, W. M., Badin, N. C., Tallassee Power Co.
Fisher, Douglas J., Sayreville, N. J., Sayre & Fisher Co.
Fisher, Geo. P., Ottawa, Ill., Superintendent, National Fireproofing Co.
Fiske, J. Parker B., Arena Bldg., New York City.
Forst, Arthur D., Trenton, N. J., President, Robertson Art Tile Co.
Fraser, W. B., Dallas, Texas, Fraser Brick Co.
Fraunfelter, Chas. D., Zanesville, Ohio, President, Ohio Pottery Co.
Freese, H. H., 446 S. Union St., Galion, Ohio, Mechanical Engineer, E. M. Freese Co.
Frost, Leon J., Geneva, N. Y., Phillips & Clark Stove Co.
Fulper, William H., Flemington, N. J., Secretary-Treasurer, Fulper Pottery.
Fulton, C. E., Creighton. Pa., Pittsburgh Plate Glass Co.
Fulweiler, Walter H., 319 Arch St., Philadelphia, Pa., United Gas Improvement Co.
Gahris, Willard I., Sebring, Ohio, Limoges China Co.
Galpin, S. L., Ames, Iowa, Professor, Department of Mining and Geology, Iowa State College.
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Gates, A. W., Colchester, Ill., Gates Fire Clay Co.
Gates, Ellis D., 1808 Prairie Ave., Chicago, Ill., American Terra Cotta and Ceramic Co.
Gates, Major E., Terra Cotta, Ill., Assistant General Manager, American Terra Cotta and Ceramic Co.
Gates William D., 1808 Prairie Ave., Chicago, Ill., President and General Manager, American Terra Cotta and Ceramic Co.
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Gelstharp, Frederick, Creighton, Pa., Pittsburgh Plate Glass Co.
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Gladding, Augustus L., Lincoln, Cal., Gladding, McBean & Co.
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Grady, Robert F., St. Louis, Mo., Manager, St. Louis Terra Cotta Co.
Grant, DeForest, 101 Park Ave., New York City, President, Federal Terra Cotta Co.
Greaves-Walker, A. F., 1454 Shady Ave., Pittsburgh, Pa., Production Manager, American Refractories Co.
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Gregory, M. E., Corning, N. Y., Proprietor, Corning Brick, Terra Cotta and Tile Co.

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Hansen, Abel, Fords, N. J., Proprietor, Fords Porcelain Works.

Hardy, Isaac E., Momence, Ill., Superintendent, Tiffany Enameled Brick Co.

Harker, H. N., East Liverpool, Ohio, President, Harker Pottery Co.

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Hart, Edward, Ph. D., Easton, Pa., Professor of Chemistry, Lafayette College.

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Hood, B. Mifflin, Candler Bldg., Atlanta, Ga., President, B. Mifflin Hood Brick Co.

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Humphrey, Harold P., Washington, N. J., Washington Porcelain Co.

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Jackson, C. E., Wheeling, W. Va., President, Warwick China Co.

Jacobs, W. M., Charleroi, Pa., Pittsburgh Plate Glass Co.
Jeffery, Joseph A., Detroit, Mich., President, Jeffery-Dewitt Co.
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Keplinger, Robert B., Canton, Ohio, Assistant General Superintendent, Metropolitan Paving Brick Co.
Kerr, C. H., 342 E. Second St., Moorestown, N. J., DeZeng-Standard Co., Camden, N. J.
Kerr, W. B., Syracuse, N. Y., President, Iroquois China Co.
Kimble, Herman K., Vineland, N. J., Manager, Scientific Glass Dept., Kimble Glass Co.
Kirk, Chas. J., New Castle, Pa., President and General Manager, Universal Sanitary Mfg Co.
Kirkpatrick, F. A., Kenova, W. Va., c/o Jeffery-Dewitt Insulator Co.
Klein, A. Albert, Worcester, Mass., Research Laboratory, Norton Co.
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***Langenbeck, Karl**, 1625 Hobart St., N. W., Washington, D. C.
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Layman, Frank E., "The Aberdeen,", Milwaukee, Wis., Cutler-Hammer Co.
Lillibridge, H. D., Zanesville, Ohio, American Encaustic Tiling Co.
Linbarger, S. C., Niagara Falls, N. Y., Carborundum Co.
Linder, Cyril S., Creighton, Pa., Pittsburgh Plate Glass Co.
Longenecker, H. L., Cambridge, Md., Manager, Cambridge Brick Co.
Loomis, George A., Washington, D. C., U. S. Bureau of Standards.

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* Life Member

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Lucas, H. J., 2525 Clybourn Ave., Chicago, Ill., Northwestern Terra Cotta Co.

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McCoy, Wm. 334 Adair Ave., Zanesville, O., Mechanical Engineer, American Encaustic Tiling Co.

McDanel, Walter W., 532 Thirteenth Ave., New Brighton, Pa.

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McDowell, J. S., Pittsburgh, Pa., Research Dept., Harbison-Walker Refractories Co.

McElroy, R. H., Dayton, Ohio, International Clay Machinery Co.

Maddock, A. M., Jr., Trenton, N. J., Vice-President, Thomas Maddock & Sons.

Maddock, Henry E., Trenton, N. J., John Maddock Sons Co.

Malm, Arthur T., 18 Orne St., Worcester, Mass., Norton Co.

Malsch, Werner, 709-717 Sixth Ave., New York City, Ceramic Department, Roessler & Hasslacher Chemical Co.

Maltby, Alfred, 70 East 3d St., Corning, N. Y., Superintendent, Brick, Terra Cotta & Tile Co.

Martens, Paul, Chrome, N. J., Metal & Thermit Corp.

Martz, Jos. A., 18th and Clark Sts., Wellsville, O., McLain Fire Brick Co.

Mayer, A. E., Beaver Falls, Pa., Assistant Secretary, Mayer Pottery Co.

Maynard, T. Poole, 1321 A Hurt Bldg., Atlanta, Ga., Consulting Geologist.

Mellor, F. G., New Castle, Pa., Shenango Pottery Co.

Miner, Harlan S., Gloucester City, N. J., Chemist, Welsbach Co.

Minton, R. H., Metuchen, N. J., General Superintendent, General Ceramics Co.

Montgomery, E. T., Franklin, Ohio, President and General Manager, Montgomery Porcelain Products Co.

Montgomery, R. J., Rochester, N. Y., Bausch & Lomb Optical Co.

Moore, Joseph K., 122 Waverly Place, New York City, Sanderson & Porter, Engineers.

Morris, Geo. D., 413 Hillcrest Ave., New Castle, Pa., Superintendent, New Castle Refractories Co.

Mossman, P. B., 315 Union Arcade, Pittsburgh, Pa., Vice-President and Treasurer, American Refractories Co.

Muckenhirn, Chas. H., 550 Chalmer Ave., Detroit, Mich., Representative, Standard Sanitary Manufacturing Company, Pittsburgh, Pa.

Munshaw, L. M., Terra Cotta, Ill., Ceramist, American Terra Cotta and Ceramic Co.

Ogden, Ellsworth P., 1957 Chelsea Rd., Columbus, O., J. B. Owens Tunnel Kilns Co.

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Donahoe, Frederic W., 840 Oliver Bldg., Pittsburgh, Pa., Secretary, The Refractories Manufacturers Association.

†**Douda, Henry W.**, 1927 Waldeck Ave., Columbus, O., U. S. Bureau of Mines.

Dougherty, Robert H., Nela Park, Cleveland, O., Assistant to Ceramic Engineer in Engineering Laboratory, National Lamp Works.

Drakenfeld, B. F., Jr., 50 Murray St., New York City, Treasurer, B. F. Drakenfeld & Co., Inc.

†**Dressler, Conrad**, 1740 E. 12th St., Cleveland, O., American Dressler Tunnel Kilns, Inc.

Dressler, Philip, 1551 E. Boulevard, Cleveland, O., American Dressler Tunnel Kilns, Inc.

Dunbar, George S., Columbus, O., Secretary, Federal Glass Co.

Durant, E. M., 603 American Bank Bldg., Los Angeles, Cal., President, Pacific Sewer Pipe Co.

Earl, Oliver N., Box 97, E. Liverpool, O., Harshaw, Fuller & Goodwin Co.

Early, Joseph W., Dickson City, Pa., Superintendent, Early Foundry Co.

Edson, S. P., Bryantville, Mass., Superintendent and Enameler, Wheeler Reflector Co.

Edwards, W. L., Tiltonsville, O., Assistant Superintendent, Wheeling Sanitary Mfg Co.

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† Elevated to Active Membership, February, 1921.

Eigenbrot, Edwin A., St. Louis, Mo., General Foreman, Buck's Stove and Range Co.

Eilers, H. F., 162 Watauga Ave., Corning, N. Y., Mechanical Engineer, Corning Glass Works.

Elledge, H. G., 3384 Webster Ave., Pittsburgh, Pa., Technical Assistant to General Sales Manager, Diamond Alkali Co.

Emminger, Thos. F., Pittsburgh, Pa., General Superintendent, Pittsburgh Clay Pot Co.

Emrick, W. A., Derry, Pa., Assistant to General Superintendent, Pittsburgh High Voltage Insulator Co.

Engle, C. C., Toms River, N. J., Assistant Manager, Crossley Mining Co.

Enright, Bernard, 1431 Collings Ave., Yorkship Village, Camden, N. J.

†**Eskesen, E. V.**, 149 Broadway, New York City, President, New Jersey Terra Cotta Co.

Evans, A. W., Zanesville, O.

Evatt, Franks G., 350 Madison Ave., New York City, Vice-President, Atlantic Terra Cotta Co.

Ewing, R. F., 1602 Clark Ave., Wellsville, O., McLain Fire Brick Co.

Farren, Mabel C., 403-A Iroquois Apartments, 3600 Forbes St., Pittsburgh, Pa.

Faulkner, Karl B., Corning, N. Y., Foreman, Pot Department, Corning Glass Works.

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Ferguson, Robert F., Pittsburgh, Pa., Mellon Institute.

†**Fettke, Charles R.**, Pittsburgh, Pa., Carnegie Institute of Technology.

Finney, Robert S., 142 W. 80th St., New York City, Parsons Trading Co.

Fisher, E. E., 2749 Monroe St., Toledo, O.

Fitz-Gerald, Gerald, Muncie, Ind., Engineer, Maxon Furnace and Engineering Co.

Fitzpatrick, John, 533 10th St., Niagara Falls, N. Y., Carborundum Co.

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Flint, Francis C., 331 South Main St., Washington, Pa., Chief Chemist, Hazel-Atlas Glass Co.

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†**Foltz, Andrew**, 187 North Union St., Lambertville, N. J., President, Lambertville Pottery Co.

†**Footitt, F. Farnsworth**, Hoboken, N. J. American Lead Pencil Co.

Ford, G. Bergen, Candler Bldg., Atlanta, Ga., B. Mifflin Hood Brick Co.

Forester, Herbert, Box 37, Cleveland, O., Principal, Veritas Firing System Co.

Forman, L. P., Arnold, Pa., American Window Glass Co.

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† Elevated to Active Membership, February, 1921.

†Forst, Daniel P., 216 West State St., Trenton, N. J., Factory Manager, Robertson Art Tile Co.

Forsyth, J. H., Cleveland, O., Associate Chemist, Glass Technology Department, National Lamp Works of G. E. Co.

Foskett, John J., 11 Neversink Ave., Port Jervis, N. Y., President and Manager, Foskett & Co., Inc.

Foster, Harry D., 266 Industrial Bldg., Washington, D. C., U. S. Bureau of Standards.

Fowler, Wm. E., Paxtonville, Pa., Paxton Brick Co.

Francais, Paul P., Box 46, Frankfort, Ind., Superintendent, Ingram-Richardson Mfg Co.

Frantz, Samuel G., Crossett, Ark., Engineer, By-Products Development, Crossett Lumber Co.

Franzheim, C. Merts, Wheeling, W. Va., The Chas. M. Franzheim Co.

Frazier, C. E., Washington, Pa., President, Simplex Engineering Co.

Frey, Wm. J., 304 W. Adams St., Sandusky, O., Superintendent, Universal Clay Products Co.

Friderichsen, Christian, 106 S. Liberty St., Independence, Mo., General Manager, Friderichsen Floor and Wall Tile Co.

†Fritz, E. H., Box 510, Derry Pa., Ceramic Engineer, Westinghouse Electric and Mfg Co.

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Fuller, J. R., 22 Highland Ave., Salem, Mass., Hygrade Lamp Co.

Fuller, Ralph L., 720 Electric Bldg., Cleveland, O., Harshaw, Fuller & Goodwin Co.

Galloway, Walter B., Philadelphia, Pa., President, Galloway Terra Cotta Co.

Garrison, Amos, 2543 S. 5th St., E., Salt Lake City, Utah.

Garrod, Fred B., Toledo, O., Chemist, Owens Bottle Co.

Gassman, H. M., 848 Brown Marx Bldg., Birmingham, Ala., Consulting Engineer.

Gavin, Gordon P., Kalamazoo, Mich., Superintendent, Kalamazoo Sanitary Mfg Co.

Gaylord, George L., 14 Holland Ave., Westfield, Mass., General Manager, Vitrified Wheel Co.

Geer, Walter, Jr., 401 Vernon Ave., Long Island City, N. Y., Vice-President, New York Architectural Terra Cotta Co.

Gehrig, Edward F., Detroit, Mich., Research Engineer, Detroit Stove Works.

Geiger, Carl F., 427 Valley St., Dayton, O., Valley Engineering Co.

†Geisinger, E. E., Rochester, N. Y., The Pfaudler Co.

†Geller, Roman F., Washington, D. C., U. S. Bureau of Standards.

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†Elevated to Active Membership, February, 1921.

George, J. S., 135 Rebecca St., Kittanning, Pa., Bureau of Standards, Pittsburgh, Pa.

George, W. C., 286 Alice St., E. Palestine, O., Vice-President, W. S. George Pottery Co.

Gernon, Ursula T., Brookings, S. D., Craft Instructor, South Dakota State College.

Giesey, V. A., 318 Citizens Bldg., Cleveland, O., President, National Refractories Co.

Gilmore, R. B., E. Liberty Branch, Y. M. C. A., Pittsburgh, Pa., Ceramic Engineer, Vesuvius Crucible Co.

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Golding, Charles E., 217 South Warren St., Trenton, N. J., Manager, Trenton Department, Golding Sons Co.

Goldsmith, B. B., 19 East 74th St., New York City, Vice-President, American Lead Pencil Co.

Gonder, Lawton G., Zanesville, O., Research Department, American Encaustic Tiling Co.

Good, Harry N., Pittsburgh, Pa., Ceramic Engineer, Pittsburgh Testing Laboratory.

Goodman, A. H., Box 915, Pittsburgh, Pa., Sales Engineer, Blaw-Knox Co.

Goodner, Ernest F., Spokane, Wash., Washington Brick, Lime and Sewer Pipe Co.

Goodwin, Herbert, New Cumberland, W. Va., Chelsea China Co.

Grace, Richard P., Woodbridge, N. J., Superintendent, Mutton Hollow Fire Brick Co.

†**Grafton, Charles O.**, Muncie, Ind., Treasurer and General Manager, Gill Clay Pot Co.

Grafton, C. V., Muncie, Ind., Treasurer and General Manager, Muncie Clay Products Co.

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Grampp, Otto, (address unknown)

Grant, Frederic J., 134 Woodlawn Ave., Zanesville, O., Mosaic Tile Co.

Grant, W. Henry, St. Marys, Pa., Elk Fire Brick Co.

Gray, Arthur E., Pittsburgh, Pa., Treasurer and General Manager, Pittsburgh Clay Pot Co.

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†Elevated to Active Membership, February, 1921.

Gray, John R., 4311 Scovel Place, Detroit, Mich., Jeffery-Dewitt Co.

Greene, R. W., Mayfield, Ky., Kentucky Construction and Improvement Co.

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Greenwood, G. W., Dunbar, Pa.

Greenwood, John L., (address unknown)

Gregori, Andrew, 16th St. and 54th Ave., Cicero, Ill., Midland Terra Cotta Co.

Gregori, John N., Chicago, Ill., Kiln Burner, Northwestern Terra Cotta Co.

Gregorius, Thomas K., Corning, N. Y., Ceramic Engineer, Corning Glass Works.

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Guthrie, Chester, Hillsboro, Ill., Pottery Foreman, Eagle-Picher Lead Co.

Guthrie, Lee, Elyria, O., Foreman, Elyria Enameled Products Co.

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Hager, Donald, 955 Brighton Blvd., Zanesville, O., Mosaic Tile Co.

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Hall, Herman A., Vanport, Pa., McLain Fire Brick Co.

Hall, William C., 1302 3d National Bank Bldg., Atlanta, Ga., Vice-President, Atlanta Terra Cotta Co.

Hamilton, James, Trenton, N. J., Superintendent, Ideal Pottery of the Trenton Potteries.

Hammer, John M., Box 555, Pittsburgh, Pa., Managing Editor, "China Glass and Lamps."

Handke, Paul A., 260 S. Academy St., Galesburg, Ill., Assistant Superintendent, Purington Paving Brick Co.

Hanna, Harold H., Crystal City, Mo., Pittsburgh Plate Glass Co.

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† Elevated to Active Membership, February, 1921.

Hansen, J. E., Pittsburgh, Pa., Industrial Fellow, Mellon Institute.
Hardesty, B. D., Beaver Falls, Pa., The Mayer China Co.
Harding, Browne, 586 Atwells Ave., Providence, R. I., Experimental Engineer, Providence Base Works of General Electric Co.
Harding, C. Knox, 6318 Stoney Island Blvd., Chicago, Ill., Consulting Engineer.
Hare, Robert L., Upper Sandusky, O., Manager, Wyandot Clay Products Co.
Harker, O. A., Jr., Puryear, Tenn., President and Manager, Dixie Brick and Tile Co.
Harper, John L., Niagara Falls, N. Y., Hydraulic Power Co.
Harrell, E. R., Checotah, Okla., Superintendent, Graham Glass Co.
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†**Harvey, F. A.**, Mt. Union, Pa., U. S. Refractories Corp.
Harvey, Ives L., Bellefonte, Pa.
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Hasslacher, Geo. F., Box 360, Cleveland, O., The Roessler & Hasslacher Chemical Co.
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Hays, George H., Cleveland, O., Assistant Manager, The Vitreous Enameling Co.
Healey, A. S., Elizabeth, N. J., Superintendent, Standard Sanitary Pottery Co.
Heath, Fred T., 4505 18th Ave., N. E., Seattle, Wash.
Heistand, Elza F., Muncie, Ind., Superintendent, Crucible Department, Gill Clay Pot Co.
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Henry, Kenneth M., San Francisco, Cal., Illinois Pacific Glass Co.
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Hepler, I. F., 207 First National Bank Bldg., Tyrone, Pa., Chief Engineer, General Refractories Co.
†**Hepplewhite, J. W.**, Pittsburgh, Pa., The Koppers Co., Mellon Institute.
Herbst, Abram W., Canaan, Conn., New England Slab Co.
Herrell, Carson, Kokomo, Ind., Secretary and Treasurer, Kokomo Sanitary Pottery Co.

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†Elevated to Active Membership, February, 1921.

Herrold, R. P., 955 Brighton Blvd., Zanesville, O., Mosaic Tile Co.
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Heuisler, Philip I., Baltimore Md., President, Maryland Glass Corp.
Hewitt, L. C., 4928-A Itaska St., St. Louis, Mo., Chief Dispatcher, Laclede-Christy Clay Products Co.
Hibbins, Thomas A., Wellsville, O., General Business and Sales Manager, The Stevenson Co.
Hibbs, Jos. S., 3203 West Columbia Ave., Philadelphia, Pa., Assistant General Manager, J. W. Paxson Co.
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Hill, Jas. H., 604-608 Pacific Electric Bldg., Los Angeles, Cal., President, Alberhill Clay and Coal Co.
Hinrichs, Carl G., 4112 Shenandoah Ave., St. Louis, Mo., Consulting and Analytical Chemist, Hinrichs Laboratories.
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Hoehl, Joseph W., Box 367, Piqua, O., Manager, Enameling Department, Favorite Stove and Range Co.
Hogenson, E., Jr., 1421-41 South 55th St., Cicero, Ill., Secretary and Treasurer, Chicago Viterous Enamel Products Co.
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Hollmeyer, John G., 4226 Hazel Ave., Edgewater Sta., Chicago, Ill., Secretary and Treasurer, American China Co.
Holmes, J. C., Sandusky, O., Superintendent, Sandusky Bulb Works.
Holmes, M. E., Ph. D., 918 G St., N. W., Washington, D. C., Manager, Chemical Department, National Lime Association.
Holstein, L. S., Palmerton, Pa., Chief of Testing Department, The New Jersey Zinc Co.
Hooper, Charles N., 4157 Western Blvd., Chicago, Ill.
Hostetler, G. R. 704 Dartmouth Ave., N. W., Canton, O.
†Hostetter, J. C., Ph. D., Corning, N. Y., Physical Chemist, Corning Glass Works.
Houk, F. J., (address unknown).
Houser, A. T., S. 30th and Jane Sts., Pittsburgh, Pa., Manager, Woods Lloyd Co.
Hower, H. S., Pittsburgh, Pa., Professor of Physics, Carnegie Institute of Technology.
Hoyler, Fritz W., Perth Amboy, N. J., Works Manager, Roessler & Hasslacher Chemical Co.

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† Elevated to Active Membership, February, 1921.

Hudson, Chas. J., 39 Kingsbury St., Worcester, Mass., Special Investigator, Norton Co.

Huisken, H. A., 1343 Wright St., Los Angeles, Cal., Los Angeles Pressed Brick Co.

Hull, W. A. Washington, D. C., Chief of Glass Section, U. S. Bureau of Standards.

Hunt, Frank S., Beaver Falls, Pa., Beaver Falls Art Tile Co.

Hunt, Marsden H., 374 Avenue E, East Pittsburgh, Pa.

Ichijo, Mokyi, New York City, care T. H. Ohyama, Woolworth Bldg.

Inman, G. E., Nela Park, Cleveland, O., Development Engineer, Lamp Development Laboratory.

Irwin, Dewitt, East Liverpool, O., Secretary, Potters Supply Co.

Jackson, H. W., DuBois, Pa,. General Manager, Jackson China Co.

Jacquart, Chas. E., South River, N. J., American Enameled Brick Co.

†**Jaeger, Frank G.**, 10th and Mullanphy Sts., St. Louis, Mo., Vice-President and General Manager, Superior Enamel Products Co.

James, W. Roy, 118 W. 14th St., Marion, Ind., Bethevan Factcry, Macbeth-Evans Glass Co.

Jenks, H. P., 614-615 Commerce Bldg., Cor. High and Spring Sts., Columbus, O., Hook Patent Kiln Co.

Jennings, Anthony J., St. Louis, Mo., Superintendent, Buck's Stove and Range Co.

Jensen, James L., 156 Greene St., Brooklyn, N. Y., Assistant Manager, Empire China Works.

Jewett, Fred E., Muncie, Ind., General Superintendent, Ball Brothers Glass Manufacturing Co.

Jewett, Richmond, Lackawanna, N. Y., Superintendent, Jewett Refrigerator Co.

Johnson, A. A. V., 1137 W. 78th St., Chicago, Ill., L. E. Rodgers Engineering Co.

Johnston, Robert M., Kenova, W. Va., Ceramic Engineer, Jeffrey- Dewitt Insulator Co.

Jones, Benjamin C., Pittsfield, Mass., Porcelain Works of General Electric Co.

Jones, Cecil, Maurer, N. J., American Encaustic Tiling Co.

†**Jones, Chester H.**, 1570 Old Colony Bldg., Chicago, Ill., Industrial Editor, "Chemical and Metallurgical Engineering."

Jones, Otis L. Oglesby, Ill., President and Manager, Illinois Clay Products Co.

Jones, Richard E., 904 Lock St., Tarentum, Pa., Pittsburgh Plate Glass Co.

Justice, Ithamar M., Dayton, O., Vice-President, Manufacturers Epuipment Co.

Kahn, Harry J., 16 General Greene Ave., Trenton, N. J.

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† Elevated to Active Membership, February, 1921.

Kahn, Isaac, 2428 Reading Road, Cincinnati, O., Owner, Wheatley Pottery Co.

Kanengeiser, Fred R., Poland, O.

Kebler, Leonard, Mt. Vernon, N. Y., Ward-Leonard Electric Co.

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†Keeler, R. B., 2505 E. 54th St., Huntington Park, Los Angeles, Cal.

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Kelly, M. J., 88 Van Dyke St., Brooklyn, N. Y., Vice-President and Manager, Brooklyn Fire Brick Works.

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Kleinfeldt, Henry F., 220 Broadway, New York City, Secretary, Abbe Engineering Co.

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Knapp, E. W., Dayton, O., Manufacturers Epuipment Co.

Knowles, H. H. Santa Clara, Cal., President, The Homer Knowles Pottery Co.

Knowles, W. V., Peoples Gas Bldg., Chicago, Ill., District Manager and Technical Representative, Titanium Alloy Manufacturing Co., Buckman & Pritchard, Inc.

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†Elevated to Active Membership, February, 1921.

Koch, Charles F., Cincinnati, O., National Sales Co.

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Koos, E. K., New Cumberland, W. Va., Chelsea China Co.

Koupal, Walter G., Creighton, Pa., Chemist, Pittsburgh Plate Glass Co.

Kraner, Hobart M., 61 Welch Ave., Columbus, O., U. S. Bureau of Mines.

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Kraus, Louis P., Jr., Klondyke, O., Vice-President, Kraus Research Laboratories, Inc.

Kraus, Lysle R., 159 Forest Ave., West Englewood, N. J., Secretary, Kraus Research Laboratories, Inc.

Krause, George, R. F. D. 1, Zanesville, O.

Krebs, A. E., South 16th St., Belleville, Ill., Belleville Enameling Works.

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Krekel, Albert, 1917 W. Fayette St, Baltimore, Md., Engineer, Porcelain Enamel and Manufacturing Co.

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†**Kurtz, John C.**, Rochester, N. Y., Bausch & Lomb Optical Co.

Kurtz, Thomas N., Claysburg, Pa., Standard Refractories Co.

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Langworthy, H. S., Jewettville, N. Y., Vice President and Superintendent, Jewettville Clay Products Co.

Lapp, G. W., Leroy, N. Y., Electrical Engineer, Lapp Insulator Co.

Lardin, R. H., Creighton, Pa., Assistant Chemist, Pittsburgh Plate Glass Co.

Larkins, Samuel B., Salineville, O., Superintendent, National China Co.

Larson, Gustaf, 503 Security Bldg., Los Angeles, Cal., Los Angeles Brick Co.

Laughlin, Samuel O., Wheeling, W. Va., President and General Manager, Wheeling Tile Co.

Lawler, John J., 839 Thomas Ave.. Forest Park, Ill., Salesman, Jas. H. Rhodes & Co.

Lawson, Carl H., 1 Wildey Ave., Worcester, Mass., Norton Co.

Lawson, George G., 2525 Clybourn Ave., Chicago, Ill., Northwestern Terra Cotta Co.

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†Elevated to Active Membership, February, 1921.

Lawton, Lewis H., Trenton, N. J., Secretary and General Manager, Jonathan Bartley Crucible Co.

Legg, Victor E., 330 Vinewood Ave., Detroit, Mich., Research Physicist, Detroit Edison Co.

Lemley, W. E., Taylor, Wash., Superintendent, Denny-Renton Clay and Coal Co.

Levings, G. v. B., Seneca, Mo., Resident Manager, American Tripoli Co.

Lewis, E. S., 29 S. LaSalle St., Chicago, Ill., Secretary-Treasurer, Advance Terra Cotta Co.

†Libman, Earl E., Urbana, Ill., Ceramic Department, University of Illinois.

Limberg, Frank, Box 505, Cincinnati, O., General Manager, Limberg Enameling Works.

Lindley, Jacob, Tiltonville, O., Riverside Potteries Co.

Lindmueller, Charles, East Chicago, Ind., Superintendent, Metal and Thermit Corp.

Lindsay, Geo. W., Denver, Col., Factory Superintendent, Denver Fire Clay Co.

Lindsay, Robert F., 2066 Albion St., Denver, Col., Denver Fire Clay Co.

Lintz, E. H., Lackawanna, N. Y., Jewett Refrigerator Co.

Lippert, Charles G., (address unknown)

Little, E. C., 1673 Railway Exchange Bldg., St. Louis, Mo., Assistant Sales Manager, Laclede-Christy Clay Products Co.

Little, H. B., Baltimore, Md., President, Baltimore Enamel and Novelty Co.

Littleton, J. T., Jr., Ph. D., Corning, N. Y., Chief, Physical Laboratory, Corning Glass Works.

Liu, S. Y., Ithaca, N. Y., Cornell University.

Livingston, H. J., Buffalo, N. Y., National Grinding Wheel Co.

Lloyd, A., Washington, Pa., Superintendent, Hazel Factory No. 2, Hazel-Atlas Glass Co.

Locke, F. M., Victor, N. Y.

Long, R. N., Woodbridge, N. J., Federal Terra Cotta Co.

Lord, F. G., Lewiston, Pa., Sales Manager, Pennsylvania Pulverizing Co.

Lord, N. W., Jr., 338 W. 8th Ave., Columbus, O., Student Ohio State University.

Louthan, Wm. B., East Liverpool, O., Manager, Louthan Manufacturing Co.

Lovatt, John, 1308 Brunswick Bldg., Trenton, N. J., Kiln Builder.

Luepke, Emil J., 2001 S. Kingshighway, St. Louis, Mo., Foreman, Quick Meal Stove Co.

Luke, Chas. H., New Bethlehem, Pa., Climax Fire Brick Co.

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† Elevated to Active Membership, February, 1921.

Luter, Clark A., 401-4 Lobe Bldg., South Gay St., Baltimore, Md., Consulting Ceramist.

Lyon, J. Boyd, St. Louis, Mo., Laclede-Christy Clay Products Co.

Lyon, P. W., 1332 Frick Bldg., Pittsburgh, Pa., Special Representative, American Sheet and Tin Plate Co.

McAllister, James E., Trenton, N. J., Ceramist, J. L. Mott Co.

McCauley, Geo. V., Corning, N. Y., Physicist, Corning Glass Works.

McClafferty, Harry J., 2124 Andrews St., Rockford, Ill., Superintendent, Rockford Viterous Enamel Co.

McCormick, O. C., Bedford, O., Bedford China Co.

McDowell, S. J., Flint, Mich., Ceramic Engineer, Champion Ignition Co.

McGee, Earle N., Syracuse, N. Y., Research Laboratory, Semet-Solvay Co.

McHose, Malcolm M., Perth Amboy, N. J., Manager, L. H. McHose, Inc.

McKaig, W. Wallace, Cumberland, Md., McKaig Machine Foundry and Supply Works, Wellington Glass Co.

McKelvey, John H., St. Louis, Mo., Sales Manager, Laclede-Christy Clay Products Co.

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McMillan, Herbert S., Detroit, Mich., Secretary and Manager, Porcelain Enameling and Manufacturing Co.

McNaughton, Malcolm, Jersey City, N. J., Superintendent, Joseph Dixon Crucible Co.

McPadden, J. H., 26 Cortlandt St., New York City, Secretary, Quigley Furnace Specialties Co.

McVay, T. M., Kenova, W. Va., Basic Products Co.

Maddock, John, Trenton, N. J., John Maddock & Sons.

Maddock, John B., Trenton, N. J., John Maddock & Sons.

Mahoney, W. T., Chattanooga, Tenn., Assistant General Manager, Cahill Iron Works.

Malinovszky, A., 316 Portland Ave., Belleville, Ill., U. S. Smelting Furnace Co.

Malkin, Wm. R., Box 669, Wheeling, W. Va.

Mandle, I., 1318 Wright Bldg., St. Louis, Mo., Secretary and Treasurer, Mandle Clay Mining Co.

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†Elevated to Active Membership, February, 1921.

Mandle, Sidney, Whitlock, Tenn., Assistant Treasurer, Mandle Clay Mining Co.

†**Manion, L. W.**, 1370 Greenfield Ave., S. W., Canton, O., Designer and Builder of Enameling Furnaces.

Manor, John M., East Liverpool, O., Manager, Golding Sons Co.

Manson, Mahlon E., Milwaukee, Wis., Chemist, Rundle Manufacturing Co.

Marks, Melville, 29 Broadway, New York City, Moore & Munger.

Marshall, P. M., 195 Broadway, New York City, Purchase Engineer, Western Electric Co., Inc.

Marshall, S. M., 1107 Broadway, New York City, Consulting Engineer, Perin & Marshall.

Martin, Earle V., Forest Grove, Ore., Forest Grove Clay Products Co.

Martin, Leonard A., 2212 E. Lake Ave., Seattle, Wash., Chemist, Denny-Renton Clay and Coal Co.

Martin, S. C., Kittanning, Pa., Kittanning Brick and Fire Clay Co.

Martin, Victor L., R. R. 7, Centralia, Ill.,

Mascn, F. Q., East Liverpool, O.

Mauschbaugh, Henry J., 806 Linn St., Peoria, Ill., Carter's Brick Yard No. 2.

Memory, N. H., 46 Bridge St., Newark, N. J., Engineer, Isbell-Porter Co.

Menne, L. H., 977 N. Main St., Rockford, Ill., Geo. D. Roper Corp.

Merica, Paul D., Ph. D., Bayonne, N. J., Superintendent of Research, International Nickel Co.

Merritt, L. M., 586 E. Long St., Columbus, O., Ceramic Engineer, Barnebey-Cheney Engineering Co.

Metz, G. F., 120 Broadway, New York City, Sales Engineer, Hardinge Co.

†**Metzner, Otto**, Cincinnati, O., Superintendent of Manufacture, Rookwood Pottery

Middleton, George E., 35 Nassau St., New York City.

Middleton, Jefferson, 1329 Randolph St., N. W., Washington, D. C., Statistician, U. S. Geological Survey.

Milford, L. R., Syracuse, N. Y., Laboratory Manager, The Solvay Process Co.

Miller, Donald M., 633 Monmouth St., Trenton, N. J., Secretary, Crossley Machine Co.

Miller, Emerson R., Zanesville, O., Salesman, Mosaic Tile Co.

Miller, Julius J., Pittsburgh, Pa., Koppers Company, Mellon Institute.

Miller, R. W., (address unknown)

Milligan, Frank W., Parkersburg, W. Va., Manager, General Porcelain Co.

Mills, H. F., Noblesville, Ind.

Minehart, A. G., Jr., Toledo, O., Manager, The Rock Products Co.

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†Elevated to Active Membership, February, 1921.

Minton, C. R., Box 14, Seville, Ohio.

Minton, G. Z., Creighton, Pa., Ceramic Engineer, Pittsburgh Plate Glass Co.

Mitchell, Leon W., Rock Island, Ill., Superintendent, Rock Island Stove Co.

Mitscherling, W. O., Ph. D., Landing, N. J., Atlas Powder Co.

Moncrieff, James W., 428 E. Pine St., Stockton, Cal.

Moore, Earl J., Bldg. Y-7, Camp Sherman, O.

Moore, E. S., Ph. D., State College, Pa., Dean, School of Mines, Pennsylvania State College.

†**Moore, Herbert W.**, 8300 Torresdale Ave., Holmesburg, Philadelphia, Pa., Precision Grinding Wheel Co.

†**Morey, George W.**, 2801 Upton St., Washington, D. C., Geophysical Laboratory.

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Morrow, Robert P., 1513 Rockefeller Bldg., Cleveland, O., Salesman, Harbison-Walker Refractories Co.

Moss, Lester M., Harrison, N. J., Superintendent, Harrison Bulb Works of General Electric Co.

Motz, W. H., Akron, O., Secretary and Treasurer, Colonial Sign and Insulator Co.

Moulding, J. W., 1203 Chamber of Commerce Bldg., Chicago, Ill., Tiffany Enameled Brick Co.

Moulton, D. A., Mexico, Mo.

†**Mueller, Theodore E.**, Louisville, Ky., General Manager, Louisville Works, Standard Sanitary Manufacturing Co.

Muessig, C. Nick, Box 267, East Liverpool, O., Salesman, B. F. Drakenfeld & Co., Inc.

Mulholland, V., 41 Arch St., Hartford, Conn.

Mumma, C. M., Lock Box E, Haviland, O., Haviland Clay Works.

Myers, Charles H., 498½ Poplar St., Murray, Utah, Superintendent, Utah Fire Clay Co.

Myers, Elmer E., Brookville, Pa., Brookville Glass and Tile Co.

Myers, Scott P., Uhrichsville, O., Uhrichsville Clay Co.

Nagle, J. A., Kenova, W. Va., Jeffery-Dewitt Insulator Co.

Nagle, Michael F., 210 John St., South Amboy, N. J., Superintendent, South Amboy Terra Cotta Co.

Navias, Louis, 203 Ceramics Bldg., University of Illinois, Urbana, Ill.

Niblock, Charles, Zanesville, O., American Encaustic Tiling Co.

Nies, Frederick, H., D. D. S., Corner Hamilton Ave. and Summit St., Brooklyn, N. Y.

Niles, Glenn H., 24 State St., New York City, Engineer, The Improved Equipment Co.

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† Elevated to Active Membership, February, 1921.

Nitchie, Charles C., Depue, Ill., Chief Chemist, Mineral Point Zinc Co.
Nolan, C. J., Toledo, O., General Manager, Modern Glass Co.,
Nye, C. P., Uniontown, Pa., Manager, Richmond Radiator Co.
Oakley, Walter W., 32 E. Second St., Corning, N. Y., Corning Glass Works.
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Ogden, D. P., Streator, Ill., Engineer, Streator Brick Co.
O'Hara, Eliot, 46 Greenwood Lane, Waltham, Mass., Manager, O'Hara Waltham Dial Co.
O'Leary, T. A., 1212 Keenan Bldg., Pittsburgh, Pa., President, T. A. O'Leary Co., Inc., and Enid Clay Co., Inc.
Olson, Peter C., 150 Nassau St., New York City.
Ossowski, Charles S., (address unknown).
Overbeck, Elizabeth G., Cambridge City, Ind., Overbeck Pottery.
Owens, F. W., 654 W. Franklin St., Baltimore, Md.
Owens, J. B., Zanesville, O.
Palmer, Ralph M., Wilmington, Del., E. I. du Pont de Nemours & Co.
Panchot, L. D., Box 325, Ford City, Pa., Second Assistant Superintendent, Pittsburgh Plate Glass Co.
Parker, George W., 1624 Railway Exchange Bldg., St. Louis, Mo., Vice-President and General Manager, Russell Engineering Company of St. Louis.
Parkinson, J. C., 704 Third Ave., Tarentum, Pa., Chemist, Pittsburgh Plate Glass Co.
Parr, John R., 224 Sinclair Place, Westfield, N. J., Manager, Sanitary Porcelain Department, General Ceramics Co.
†Pass, R. H., Syracuse, N. Y., Onondaga Pottery Co.
Patch, James B., 40 Howard St., Millville, N. J., Chemist, Whitall Tatum Co.
Patten, D. M., Chattanooga, Tenn., Treasurer, Chattanooga Stamping and Enameling Co.
Paul, Joseph R., Newark, Cal., Enamel Foreman, Graham Mfg Co.
Paul, William W., 1550 W. Euclid St., Detroit, Mich., Superintendent, Wolverine Porcelain Enameling Co.
†Payne, A. R., Clarksburg, W. Va., Chief Physicist, Hazel Atlas Glass Co.
Pearson, Howard L., Mexico, Mo., Engineer, A. P. Green Fire Brick Co.
†Peck, Albert B., Ann Arbor, Mich., Mineralogical Laboratory, University of Michigan.
Pellerano, Silvio, 1837 Seventy-first St., Brooklyn, N. Y., Assistant Chemist, Hemming Mfg Co., Garfield, N. J.

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† Elevated to Active Membership, February, 1921.

Pelton, Herbert E., 844 Fifth Ave., Los Angeles, Cal., Secretary and Treasurer, West Coast Tile Co., Inc.

Pendrup, W., Cicero, Ill., Superintendent, Enameling Department, Coonley Mfg Co.

Penfield, L. W., Bucyrus, O., Hadfield-Penfield Steel Co.

Penfield, R. C., 1619 Conway Bldg., Chicago, Ill., Hadfield-Penfield Steel Co.

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Pfalzgraf, Charles F., Baltimore, Md., President, Baltimore Stamping and Enameling Co.

Pfeiff, C. H., 145 Rector St., Perth Amboy, N. J., Superintendent, General Ceramics Co.

Philips, Wilson A., Trenton, N. J., President, Philips-Harper Co.

Phillips, William L., 1016 San Antonio Ave., Alameda, Cal., N. Clark & Sons.

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Pitcock, Lawrence, Crooksville, O., Superintendent, Crooksville China Co.

Pohle, Louis, 690 Princeton Ave., Trenton, N. J.

Pohs, Frank J., 500 Roselawn Ave., Portland, Ore., Portland Stove Works.

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Porter, F. B., 204½ Houston St., Fort Worth, Tex., President, Fort Worth Laboratories.

Porter, J. Edward, Box 785, Syracuse, N. Y., Chemical Laboratory, Porter & Clancy.

Post, Albert H., Waterville, Conn., Superintendent, Gordon Electric Manufacturing Co.

†**Post, M. P.**, Commerce, Mo., Superintendent, Post Brothers.

Potter, William A., Richmond, Cal., Factory Manager, Pacific Porcelain Ware Co.

Powell, R. E., 8700 S. State St., Chicago, Ill., Chief Engineer, Federal Electric Co.

Preston, F. C., 509 Cuyahoga Bldg., Cleveland, O., Vice President and Sales Manager. Dover Fire Brick Co.

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†Elevated to Active Membership. February, 1921.

Primley, Walter S., 1014 Chamber of Commerce Bldg., Chicago, Ill., Midland Terra Cotta Co.

Pritchard, G. A., 94 Fulton St., New York City, Second Vice President, Buckman & Pritchard, Inc.

Proodian, E. K., (address unknown)

Pulsifer, H. M., (address unknown).

Pyatt, Frank E., Perrysville, O.

Quaintance, Charles F., Golden, Col., Secretary, Coors Porcelain Co.

Rabun, Wiley T., 124 N. Santa Fe Ave., Huntington Park, Los Angeles, Cal., Foundryman, Whiting-Mead Commercial Co.

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Rahn, Robert C., 4642 West End Ave., Chicago, Ill., Ceramic Engineer, Western Electric Co.

Raiff, David A., Coshocton, O., Enameler, Beach Enameling Co.

Ramsay, Andrew, Mt. Savage, Md., The Andrew Ramsay Co.

†Ramsay, J. D., St. Marys, Pa., President and General Manager, Elk Fire Brick Co.

Ramsdell, Lewis S., 29 West St., Worcester, Mass., Norton Co.

Rancke, Louis, N., 12th and M. Sts., S. E., Washington, D. C., Consulting Engineer-Chemist.

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Rawson, Cummins, Des Moines, Ia., Iowa Pipe and Tile Co.

Reagan, F. H., Victor, N. Y., General Manager, Locke Insulator Co.

Reddick, W. L., Grafton, W. Va., Superintendent, Hazel-Atlas Glass Co.

Reeb, H. E., 269 S. 18th St., Columbus, O.

Reed, Adam, Zanesville, O., President, Peters & Reed Pottery Co.

Reedy, A. J., Battle Creek, Mich., Superintendent, A–B Stove Co.

Reid, W. H., 10 Stanley Place, Yonkers, N. Y., Consolidated Gas Company of New York.

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Rentschler, M. J., Willoughby, O., General Manager, J. H. R. Products Co.

Rhead, Mrs. Frederick H., Zanesville, O.

Rhead, Harry W., 144 Putnam Ave., Zanesville, O., Designer, Roseville Pottery Co.

Rhcads, Ralph S., (address unknown)

Rhodes, George E., 1609 N. Webster St., Kokomo, Ind., Vice President and General Manager, Kokomo Sanitary Pottery Co.

Riblet, Bertha, 2047 E. 115th St., Cleveland, O.

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†Elevated to Active Membership, February, 1921.

Richard, L. M., 1401 Rialto Blvd., Venice, Cal.
Richardson, E. A., Toledo, O., Libbey Glass Manufacturing Co.
Richardson, P. B., 210 Otis St., East Cambridge, Mass., Salesman, Harbison-Walker Sales Co.
Riley, R. J., Indianapolis, Ind., Indianapolis Terra Cotta Co.
Risch, Edward J., 4742 W. Adams St., Chicago, Ill., Head Draftsman, Midland Terra Cotta Co.
Ritschy, Donald P., Tacony, Philadelphia, Pa., Keystone Lantern Co.
Ritter, J. F., Evansville, Ind., Manager, Evansville Enameling Co.
Rixford, Guy L., Rocky River, Cleveland, Ohio, Cowan Pottery..
Roberts, Frank G., 8th and O'Donnel Sts., Baltimore, Md., Service Engineer, Porcelain Enamel and Manufacturing Co.
Roberts, Jane E., Iowa City, Ia., Librarian, State University of Iowa.
Robertson, Fred H., 809 North Alvarado St., Los Angeles, Cal., Los Angeles Pressed Brick Co.
Robertson, H. S., Pittsburgh, Pa., Harbison-Walker Refractories Co.
Robineau, S. E., 108 Pearl St., Syracuse, N. Y., President, Keramic Studio Publishing Co.
Robinson, J. D., Toledo, O., President, Libbey Glass Manufacturing Co.
Robinson, Louis G., Harrison Bldg., Cincinnati, O., Cincinnati Testing Bureau.
†**Rochow, W. F.**, Pittsburgh, Pa., Chemical Engineer, Harbison-Walker Refractories Co.
Roddewig, Ed., 411 Harrison St., Davenport, Ia.
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Rogers, Gregory L., Renton, Wash., Denny-Renton Clay and Coal Co.
Rogers, Jas. B., 6231 St. Lawrence Ave., Chicago, Ill., Experimental Engineer.
Rogers, Thomas S., Chicago, Ill., Special Representative, National Silica Co.
Roll, Edw. E., 1037 Ansel Rd., Cleveland, O.
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Rusoff, Samuel, Anderson, Ind., Ceramic Engineer, National Tile Co.
†**Russel, John W.**, 522 Chestnut St., Columbia, Pa., President, Marietta Hollow Ware and Enameling Co.
Ryan, John F., Woodbridge, N. J., Secretary and Manager, Mutton Hollow Fire Brick Co.
Ryan, J. J., 810 Sumpter Bldg., Dallas, Tex., Production Manager, Secretary-Treasurer, Fraser Brick Co.
Ryan, Lawrence C., Woodbridge, N. J., Assistant Manager, Mutton Hollow Fire Brick Co.
Ryan, P. Joseph, Woodbridge, N. J., President, Mutton Hollow Fire Brick Co.

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† Elevated to Active Membership, February, 1921.

Sant, Richard C., East Liverpool, O., Secretary, The John Sant & Sons Co.

Sassetti, F. L., 114 E. Grand Ave., Chicago, Ill., Florence Art Co.

Sauereisen, C. Fred, 1335 Point View St., Pittsburgh, Pa.

Saunders, A. E., 142 Kingsland Ave., Corona, L. I., N. Y.

Saunders, Lewis E., 262 Salisbury St., Worcester, Mass., Manager, Research and Abrasive Plants, Norton Co.

Saxe, C. W., 54 W. Boylston St., Worcester, Mass., Norton Co.

Schaeffer, John A., St. Louis, Mo., Vice-President, Eagle-Picher Lead Co.

Schermerhorn, Joseph A., 938 Carteret Ave., Trenton, N. J., Trenton Porcelain Co.

Schmid, A. F., 1400 Wheeling Ave., Zanesville, O., Superintendent, Zanesville Art Pottery Co.

†Scholes, Samuel R., Ph. D., Columbus, O., Chemist, Federal Glass Co.

Schoneich, Philip A., Pittsfield, Mass., General Foreman, Pittsfield Porcelain Works.

Schramm, Edward, 574 Whittier Ave., Syracuse, N. Y., Research Chemist, Onondaga Pottery Co.

Schulze, John F. W., Edgewood, Md., Edgewood Arsenal.

Schurtz, D. D., Lancaster, O., Sharp-Schurtz Co.

Schwetye, Fred H., St. Louis, Mo., Superintendent, Laclede-Christy Clay Products Co.

Scott, David H., Muncie, Ind., Ball Brothers Glass Manufacturing Co.

Scott, M. R., 1220 Lake Ave., Rochester, N. Y., Bausch & Lomb Optical Co.

Seasholtz, J. M., Front and Spruce Sts., Reading, Pa., Owner, Porcelain Enameling Plant.

Sebring, F. H., Jr., Salem, O., President, The Salem China Co.

Sewell, Sidney I., Arnold, Pa., American Window Glass Co.

†Sharp, Chester L., Lancaster, O., Sharp-Schurtz Co.

Sharp, Donald E., Hamburg, N. Y., Spencer Lens Co.

†Shaw, L. I., Ph. D., Washington, D. C., Assistant Chief Chemist, U. S. Bureau of Mines.

Shaw, Lucian, West Lafayette, O., Secretary, The West Lafayette Manufacturing Co.

Sheehy, J. F., Newport, Ky., Superintendent and Manager, Alhambra Tile Co.

Sheppard, Mark, Norristown, Pa., E. J. Lavino & Co.

Sherwood, Robert, 143 Industrial Bldg., Washington, D. C., U. S. Bureau of Standards.

Shively, R. R., Ph. D., Fairmont, W. Va., Chemical Engineer, Monongah Glass Co.

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† Elevated to Active Membership, February, 1921.

Short, Frank, University Club, Washington, D. C., Expert in Aircraft Armament, Ordnance Department, Frankford Arsenal.

Shultz, J. Emmet, Zanesville, O., Modeler, American Encaustic Tiling Co.

Silver, Anna K., 9 Hawthorne St., Worcester, Mass., Analytical Division, Norton Co.

Silvers, James L., Trenton, N. J., Manager, Trent Tile Co., Inc.

Sladek, George E., Beaver Falls, Pa., Beaver Falls Art Tile Co.

Slater, W. M., 622 F St., N. W., Washington, D. C., President, American Rutile Co.

Sloan, Alex, Box 410, Cumberland, Md., Manufacturing Chemist.

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Smith, Harry W., Box 360, Cleveland, O., Roessler & Hasslacher Chemical Co.

Smith, H. Dan, East Liverpool, O., Superintendent, Smith-Phillips China Co.

Smith, Maurice A., Jeanette, Pa., Vice-President and General Manager, McKee Glass Co.

Smith, Norman G., Brunswick, Me., Manager and Treasurer, Maine Feldspar Co.

Smith, Perry A., New Brighton, Pa., Secretary, A. F. Smith Co.

Smith, R. G., Fort Worth, Texas, Plant Manager, Acme Brick Co.

Smith, Wilbur R., Minotola, N. J., Illinois Glass Co.

Smoot, C. E., 1900 Santa Fe Ave., Los Angeles, Cal., President American Enameling and Stamping Co.

Smyser, Albert E., 239 South Fairmount St., E. E., Pittsburgh, Pa., Engineer of Refractories, Koppers Co.

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†**Sortwell, H. H.**, 143 Industrial Bldg., Washington, D. C., U. S. Bureau of Standards.

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Stallings, A. G. T., Mexico, Mo., Superintendent, A. P. Green Fire Brick Co.

Stangl, J. M., Flemington, N. J., Factory Manager, Fulper Pottery Co.

Stepan, A. C., 589 E. Illinois St., Chicago, Ill., Manager, Roessler & Hasslacher Chemical Co.

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†Elevated to Active Membership, February, 1921.

Stern, Newton W., 67 New Montgomery St., San Francisco, Cal., Secretary and Treasurer, Pacific Porcelain Ware Co.

Stevenson, Wm. G., Oregon, Ill., Secretary-Treasurer, Ohio Silica Co.

Stewart, Andrew H., Pittsburgh, Pa., Mellon Institute.

Stewart, John G., 530 Union Trust Bldg., Cincinnati, O., District Manager, Stephens Adamson Mfg Co., Aurora, Ill.

Stockdale, V. B., 609 W. Meek St., Abingdon, Ill., Superintendent, Abingdon Sanitary Mfg Co.

Stockton-Abbott, Lyle, 11 Broadway, New York City, Celite Products Co.

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†Stone, Charles H., Jr., 11110 Detroit Ave., Cleveland, O., Research and Industrial Chemist, Kemet Laboratories Co.

Stone, George C., 160 Front St., New York City, New Jersey Zinc Co.

Stoneman, Wm. N., Charleroi, Pa., Chemist, Macbeth Evans Glass Co.

Storey, O. W., Madison, Wis., Metallurgist, C. F. Burgess Laboratories.

Stover, J. Homer, 176 Grant Ave., Nutley, N. J., Sales Manager, John Johnson Co., Brooklyn.

Stowe, G. T., Leader News Bldg., Cleveland, O., The Cleveland Builders Supply and Brick Co.

Strommer, L. T., 13507 Garden Ave., East Cleveland, O., American Dressler Tunnel Kilns, Inc.

†Strong, Thos. L., West Lafayette, O., General Manager, Lafayette Stamping and Enameling Co.

Stull, Jos. M., Crum Lynne, Pa., Ceramist, O. W. Ketcham Terra Cotta Works.

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Swift, George C., 2029 E. 115th St., Cleveland, O., Superintendent, Enamel Products Co.

Swinnerton, B. B., 126 E. Main St., Lancaster, O., American Dressler Tunnel Kilns, Inc.

Swope, H. J., Quincy, Ill., Business Manager, Economy Enameling Co.

Tait, Howard J., Monaca, Pa., Phœnix Glass Co.

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Taylor, R. F., 40 Falls St., Niagara Falls, N. Y.

Taylor, R. P., Roseland, Nelson Co., Va., Superintendent, Klimax Kaolin Co.

Taylor, Wm. C., Corning, N. Y., Corning Glass Works.

Tefft, T. Dwight (address unknown)

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† Elevated to Active Membership, February, 1921.

Thomas, Chauncey R., 2336 San Pablo Ave., Berkeley, Cal., "The Tile Shop."

Thomas, George E., St. Louis, Mo., General Superintendent, Highlands Fire Clay Co.

Thomas, George W., East Liverpool, O., President, R. Thomas & Sons Co.

Thomas, James R., Crawfordsville, Ind., Manager, Standard Brick Co.

Thompson, Harry M., Washington, Pa., Furnace Engineer, Simplex Engineering Co.

Thurliman, Leo, 4716 N. Talman Ave., Chicago, Ill.

Thwing, C. B., Ph. D., Philadelphia, Pa., President, Thwing Instrument Co.

Tiebout, Cornelius H., Jr., 99 Commercial St., Brooklyn, N. Y., Gleason-Tiebout Glass Co.

Tillotson, George S., 43 Water St., Tiffin, O., Sterling Grinding Wheel Co.

Tilton, C. B., 21 Elbridge St., Worcester, Mass., Norton Co.

Timmerman, Walter F., Kansas City, Kan., Vice President, Western Terra Cotta Co.

Trace, A. R., Hobart, Ind., National Fire Proofing Co.

Trifonoff, Boris, Zanesville, O., American Encaustic Tiling Co.

Trood, Samuel (address unknown)

Troutman, Frank E., Butler, Pa., Secretary-Treasurer, Standard Plate Glass Co.

Trowbridge, Prentiss S., 1337 Kings Highway, St. Louis, Mo., Hydraulic Pressed Brick Co.

Truby, H. A., Creighton, Pa., Research Department, Pittsburgh Plate Glass Co.

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Turner, James, Trenton, N. J., Cook China Co.

Twells, Robert, Jr., 4401 Avery St., Detroit, Mich., Jeffery-Dewitt Co.

Twining, F. E., Fresno, Cal., Manager, The Twining Laboratories.

†**Tyler, H. B.**, 216 Gibson St., Canandaigua, N. Y., Superintendent, Enamel Department, Lisk Manufacturing Co.

Unger, J. S., 1054 Frick Annex, Pittsburgh, Pa., Manager, Central Research Bureau, Carnegie Steel Co.

Vance, Edward D., Springfield, O., Ceramic Engineer, Safety Emery Wheel Co.

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† Elevated to Active Membership, February, 1921.

VanCleave, A. A., 5031 Tyler Ave., St. Louis, Mo.

Vane, A. S., 8300 Torresdale Ave., Philadelphia, Pa., Precision Grinding Wheel Co., Inc.

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Vincent, Harry S., Fort Dodge, Ia., President, Vincent Clay Products Co.

Vodick, William J., 1733 Lake Ave., Wilmette, Ill., Chicago Hardware Foundry Co.

Vogt, C. C., Pittsburgh, Pa., Mellon Institute.

†Vollkommer, Josef, Bessemer Bldg., Pittsburgh, Pa., President and Manager, Vitro Manufacturing Co.

Vollmer, August, Jr., 5240-46 Northrup Ave., St. Louis, Mo., St. Louis Pottery and Manufacturing Co.

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Walcott, A. J., 41 Prince St., Rochester, N. Y., Research Physicist, Bausch & Lomb Optical Co.

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Walton, H. K., 59 Pearl St., New York City, New York Agent, Thwing Instrument Co.

†Walton, S. F., 110 Brookline Ave., Boston, Mass., Kalmus, Comstock & Wescott, Inc.

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Watson, Harold L., West Lynn, Mass., Research Division Optical Glass, Thomson Laboratory, General Electric Co.

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Weigel, Chas., Hebron, N. Dak., President, Hebron Fire and Pressed Brick Co.

† Elevated to Active Membership, February, 1921.

†**Weil, Edgar H.**, Cleveland, O., President, Vitreous Enameling Co.

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Wenning, W. F., 3313 Allendale St., Pittsburgh, Pa., Research Department, Vitro Manufacturing Co.

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Wey, Harold B., 1302 Third National Bank Bldg., Atlanta, Ga., Vice President and General Manager, Atlanta Terra Cotta Co.

Wherry, James B., Omaha, Neb., Research Chemist, Refinite Co.

White, Ray H., Niagara Falls, N. Y., Research Engineer, Norton Co.

White, Richard P., 121 S. Menard Ave., Chicago, Ill., Secretary-Treasurer, Union Stoneware Co.

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Williams, John A., Prospect St. and P. & R. R. R., Trenton, N. J., Factory Manager, Mitchell-Bissell Co.

†**Williams, Warren S.**, Arnold, Pa., American Window Glass Co.

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Ayars, E. E.
Butterworth, Frank W.
Stevens, Douglas F.

Depue

Nitchie, Chas C.

Des Plaines

Benjamin Electric Mfg Co.
Radcliffe, B. S.

Dudley

Yowell, J. B.

Dundee

Haeger, E. H.

Evanston

Rapp, John A.

Forest Park

Lawler, John J.

Galesburg

Bates, Charles E.
Handke, Paul A.
Springe, Otto

Granite City

Buck, W. E.

Hillsboro

Guthrie, Chester

Joliet

Austin, G. L.
Krusen, I. Andrew

Momence

Hardy, Isaac E.

Monmouth

Dains, I. F.
Western Stoneware Co.

Murphysboro

Bautz, Robert A.

Ogelsby

Jones, Otis L.

Oregon

Stevenson, Wm. G.

Ottawa

Bissell, G. F.
Fisher, Geo. P.
Van Schoick, E. H.

Peoria

Carter, B. F.
Carter, C. E.
Mauschbaugh, Henry J.

Quincy

Swope, H. J.

Robinson

Bonner, James M. Jr.
Zwermann, Carl H.

Rockford

McClafferty, Harry J.
Menne, L. H.

Rock Island

Coulston, E. V.
Mitchell, Leon W.

Streator

McCann, J. S.
Ogden, D. P.
Streator Clay Mfg. Co.

Terra Cotta

Clark, Ernest
Gates, Major E.
Munshaw, L. M.

Urbana

Hursh, Ralph K.
Libman, Earl E.
Navias, Louis
Parmelee, C. W.
Polk, Arthur E.
Washburn, E. W.

Wilmette

Vodick, William J.

INDIANA

Anderson
Rusoff, Samuel

Brazil
Shoemaker, Geo. W.

Cambridge City
Overbeck, Elizabeth G.

Colfax
Casey, J. B.

Crawfordsville
Thomas, James R.

Decatur
Krick, George M.

East Chicago
Lindmueller, Chas.
Yuill, John W.

Evansville
Ritter, J. F.

Frankfort
Francais, Paul P.

Hartford City
Crimmel, H. H.

Hobart
Trace, A. R.

Indianapolis
Burgess, M. L.
Landers, Wm. F.
Randall, J. E.
Randall, T. A.
Riley, R. J.

Kokomo
Coxon, J. B.
Herrell, Carson
Rhodes, George E.
Wright, Harry E.

Marion
James, W. Roy

Muncie
Fitz-Gerald, Gerald
Grafton, Chas. O.
Grafton, C. V.
Heistand, Elza F.
Jewett, Fred E.
Scott, David H.

Noblesville
Mills, H. F.

Peru
Burton, Charles G.
Spurrier, Harry
Square D Co.

Portland
Fulton, Kenneth I.

Terre Haute
Cooke, Raymond D.

Winchester
Yingling, Walter A.

IOWA

Ames
Borg, H. E.
Cox, Paul E.
Galpin, Sydney L.
Whittemore, John W.

Davenport
Roddewig, Ed

Des Moines
Rawson, Cummins

Fort Dodge
Vincent, Harry S.

Iowa City
Roberts, Jane E.

Mason City
Dailey, Ernest W.

Perry
Borg, H. E.

Postville
Bickel, Earl A.

Sheffield
Carhart, C. C.
Whittemore, O. J.

KANSAS

Lawrence
Coates, W. W. Jr.
Teetor, Paul

Kansas City
Timmerman, Walter F.

KENTUCKY

Cloverport
Bowne, Edward

Covington
Berger, William S.

Louisville
Mueller, Theodore E.

Mayfield
Greene, R. W.

Newport
Sheehy, J. F.
Webster, Henry

MAINE

Auburn
Maine Feldspar Co.

Brunswick
Smith, Norman G.

MARYLAND

Baltimore
Dornbach, Wm. E.
Heuisler, Philip I.
Jones Hollow Ware Co.
King, Earl O.
Krekel, Albert
Little, H. B.
Luter, Clark A.
Owens, F. W.
Pfalzgraf, Chas. F.
Roberts, Frank G.
Turk, Karl
Worsham, Edgar A.

Cambridge
Longenecker, H. L.

Cumberland
McKaig, W. Wallace
Sloan, Alex

Edgewood
Becque, J. H.
Schulze, John F. W.

Mt. Savage
Ramsay, Andrew

Mt. Winans
Crownover, A. W.

North East
Cameron, A. C.

MASSACHUSETTS

Boston
Walton, S. F.

Chester
Maxf Grinding Wheel Corp.

East Boston
Slobodkin, S. H.

Bryantville
Edson, S. P.

East Cambridge
Richardson, P. B.

Gardner
Anderson, John A.

Great Barrington
Barth, Victor

Holden
Booze, M. C.

Leominster
Charron, R. C.

Lynn
Wry, Thomas A.

Marblehead
Baggs, Arthur E.

Pittsfield
Jones, Benjamin C.
Schoneich, Philip A.

Salem
Fuller, J. R.

Southbridge
Boyden, Mrs. E. S.

Taunton
Anthony, Wm. R.

Waltham
Austin, James L.
Cunningham, Matthias F.
Flagg, Frederick P.
O'Hara, Eliot

Westfield
Gaylord, George L.

West Lynn
Watson, Harold L.

Winchendon
Bassett, Leon B.

Woburn
Blodgett, Malcolm

Worcester
Anderson, Robert E.
Beecher, Milton F.
Broga, Wilson C.
Buckner, O. S.
Chaffin, Edwin G.
Chapman, Dorothy P.
Hudson, Chas. J.
Jeppson, Geo. N.
Klein, A. Albert
Lawson, Carl H.
Malm, Arthur T.
Norton Co.
Ramsdell, Lewis E.
Saunders, Lewis E.
Saxe, Chas. W.
Silver, Anna K.
Tilton, C. B.

MICHIGAN

Ann Arbor
Peck, Albert B.

Battle Creek
Reedy, A. J.

Detroit
Betteley, Albert G.
Carrier, Augustus
Davenport, R. W.
Gehrig, Edward F.
Gray, John R.
Jeffery, Joseph A.
Jeffery-Dewitt Co.
Kempf, John R.
Kent, G. G.
Laird, J. S.
Legg, Victor E.
McMillan, Herbert S.
Muckenhirn, Chas. H.
Paul, Wm. W.
Riddle, F. H.
Twells, Robert, Jr.

Flint
Bergmans, Carl
Brenholtz, W. K.
Champion Ignition Co.
Helser, P. D.
McDougal, Taine G.
McDowell, S. J.

Grand Haven
Grainer, John S.

Grand Ledge
Benner, Wm. J.

Grand Rapids
Bardush, J. F.

Kalamazoo
Gavin, Gordon P.
Perg, Carl

Saginaw
Kendrick, Lucius S.

MINNESOTA

St. Paul
Ahrens, Robert S.
Koch, A. L.
Rathjens, G. W.

MISSISSIPPI

Enid
Bramlett, Mrs. Julian T.

MISSOURI

Commerce
Post, M. P.

Crystal City
Hanna, Harold H.

Florissant
Godejohn, W. F.

Independence
Friderichsen, Christian

Kansas City
Dickey, Fred L.

Kirkwood
Bridge, Laurence D.

Mexico
Moulton, D. A.
Pearson, Howard L.
Stallings, A. G. T.

Seneca
Levings, G. V. B.

St. Louis
Arnold, Howard C.
Bausch, Frederic E.
Bell, Fred S.
Berry, Chas. W.
Blackmer, E. L.
Christopher, Arthur B.
Colburn, Ed D.
Dana, Leslie
Dell, John M.
Dimcombe, G. M. Jr.
Eigenbrot, Edwin A.
Grady, Robert F.
Green, J. L.
Hahn, Carl A.
Hail, Walter
Hatton, Richard D.
Hewitt, L. C.
Hinrichs, Carl G.
Ittner, W. W.
Jaeger, Frank G.
Jennings, Anthony J.
Kimberling, Henry R.
Koch, Julius J.
Laclede-Christy Clay Products Co.
Laird, Charles
Little, E. C.
Luepke, Emil J.
Lyon, J. Boyd
McKelvey, John H.
Mandle, I.
Mitchell Clay Mfg. Co.
Parker, Geo. W.
Parker, Lemon
Russell Engineering Co.
Schaeffer, John A.
Schwetye, Fred H.
Thomas, George E.
Trowbridge, Prentiss S.
Truman, Gail R.
VanCleave, A. A.
Vollmer, August, Jr.
Wheeler, Herbert A.

MONTANA

Helena
Bray, Archie C.

NEBRASKA

Lincoln
Ferguson, Richard D.

Omaha
Wherry, Jas. B.

NEW JERSEY

Bayonne
Merica, Paul D.

Camden
Dobbins, T. Monroe
Enright, Bernard
Kerr, Chas. H.

Chrome
Martens, Paul

East Orange
Brann, Albert

Elizabeth
Healey, A. S.

Flemington
Fulper, Wm. H.
Stangl, J. M.

Fords
Brinkman, S. G.
Hansen, Abel

Glen Ridge
Cox, Harold N.

Gloucester City
Miner, Harlan S.

Haddonfield
Yearsley, Howard L.

Harrison
Koerner, Walter E.
Moss, Lester M.
Yung, W. A.

Hoboken
Footitt, F. Farnsworth
Keuffel, Carl W.

Jamesburg
Foersterling, Hans

Jersey City
Acheson, Albert E.
Depneler, J. H.
McNaughton, Malcolm

Keasbey
Whitaker, Fred A.

Lambertville
Foltz, Andrew

Landing
Mitscherling, W. O.

Matawan
Barker, Charles E.
Eskesen, Bennet K.
Matawan Tile Co.

Maurer
Jones, Cecil

Metuchen
Bloomfield, Chas. A.
Bloomfield, Howard W.
Campbell, A. R.
Edgar, David R.
The Edgar Plastic Kaolin Co.
Minton, R. H.

Millville
Barton, G. E.
Patch, James B.
Whitall-Tatum Co.

Minotola
Smith, Wilbur R.

Newark
Allison, LeRoy W.
Hanovia Chemical & Mfg. Co.
Memory, N. H.

New Brunswick
Brown, Geo. H.

Nutley
Stover, J. Homer

Old Bridge
DeVoe, Chas. H.
Old Bridge Enameled Brick & Tile Co.

Perth Amboy
Brennan, Geo. L.
Bruner, Willard L.
Geiger, Charles F.
Grueby, Wm. H.
Hill, Charles W.
Howat, Walter L.
Hoyler, Fritz W.
McHose, Malcolm M.
Perth Amboy Tile Co.
Pfeiff, Carl Heinrich
Roessler, Franz
Staudt, August
Will, Otto W.

Rahway
Balz, Geo. A.

Sayreville
Fisher, Douglas J.

South Amboy

Nagle, Michael F.
Tatton, Joseph

South River

Jacquart, Chas. E.
Wright, Marcus S.

Tenafly

Solon, Leon V.

Toms River

Engle, C. C.

Trenton

Bedson, William
Boughey, Joseph
Bowman, Oliver O.
Bowman, Wm. J. J.
Briggs, Leonard S.
Brown, Leslie
Burroughs, Francis H.
Chambers, A. R.
Cook, Chas. .
Dennis, J. Alfred
Dinsmore, B. B .
Forst, Arthur D.
Forst, Daniel P.
Golding, Chas. E.
Hamilton, James
Hoffman, Geo. E.
Kahn, Harry J.
Lawton, Lewis H.
Lovatt, John
Maddock, A. M., Jr.
Maddock, Henry E.
Maddock, John
Maddock, John B.
McAllister, James E.
Miller, Donald M.
Philips, Wilson A.
Pohle, Louis
Schermerhorn, Joseph A.
Silvers, James L.
Simcoe, George
Sinclair, Herbert
Solon, Marc
Star Porcelain Co.
Stover, Edward C.
Trenton Flint & Spar Co.
Turner, James
Veritas Firing System
Wainford, Richard H.
Whitehead, Fred
Wilkinson, Samuel
Williams, John A.
Wright, John M.

Vineland

Kimble, Herman K.

Washington

Humphrey, Harold P.

West Englewood

Kraus, Lysle R.

Westfield

Parr, John R.

Woodbridge

Allen, F. B.
Clare, R. L.
Grace, Richard P.
Kreger, John M.
Long, R. N.
Ryan, John F.
Ryan, Lawrence C.
Ryan, P. Joseph

NEW YORK

Alfred

Binns, Chas. F.
Binns, Norah W.
Castro Oliveira, Rodolfo
Collin, Louis
Shaw, Joseph B.

Angola

Balmert, R. M.

Astoria

Clark, John

Bronxville

Waller, Alfred E.

Brooklyn

Gleason, Marshall W.
Gleason-Tiebout Glass Co.
Jensen, Chas. H.
Jensen, James Lawrence
Kelly, M. J.
Kraus, Chas. E.
Nies, Frederick H.
Pellerano, Silvio
Tiebout, Cornelius H.

Buffalo

Agge, Franklin
Livingston, H. J.
Rea, Wm. J.
Worsham, Herman

Canandaigua

Keehn, Clarence C.
Kennedy, John H.
Tyler, H. B.

Canastota

Crawford, Edw. A.

Corning
- Carder, Frederic R.
- Eilers, H. F.
- Faulkner, Karl B.
- Gregorius, Thos. K.
- Gregory, M. C.
- Gregory, M. E.
- Hostetter, J. C.
- Littleton, J. T., Jr.
- McCauley, Geo. V.
- Maltby, Alfred
- Oakley, Walter W.
- Sullivan, E. C.
- Taylor, Wm. C.

Corona
- Saunders, A. E.

Cortland
- Cortland Grinding Wheel Co.

Geneva
- Frost, Leon J.

Hamburg
- Sharp, Donald E.

Ithaca
- Liu, S. Y.
- Ries, Heinrich

Jewettville
- Langworthy, H. S.

Lackawanna
- Jewett, Richmond
- Lintz, E. H.

LeRoy
- Lapp, G. W.

Long Island City
- Dalton, Richard F.
- Geer, Walter, Jr.
- Tucker, Gus M.

Mt. Vernon
- Kebler, Leonard

New York City
- Acheson, Edward G.
- Alexander Hamilton Institute
- Bartlett, John H., Jr.
- Booraem, J. Francis
- Brooks, B. T.
- Cooper, George W.
- Crane, Chas. W.
- Drakenfeld, B. F., Jr.
- B. F. Drakenfeld Co.
- Engelhard, Charles, Inc.
- Eskesen, E. V.
- Evatt, Franks G.
- Farnham, D. T.
- Finney, Robert Spencer
- Fiske, J. Parker B.
- General Ceramics Co.
- Goldsmith, B. B.
- Grant, Deforest
- Guastavino, Rafael, Jr.
- Ichijo, Mokiji
- Kingsbury, Percy C.
- Kleinfeldt, Henry F.
- Lamborn, Lloyd
- McPadden, J. H.
- Malsch, Werner
- Marks, Melville
- Marshall, P. M.
- Marshall, S. M.
- Metz, G. F.
- Middleton, G. E.
- Moore, Joseph K.
- Moore and Munger
- Niles, Glenn H.
- Olsen, Peter C.
- Pitcairn, Wm. S.
- Powell, Wm. H.
- Pritchard, Geo. A.
- Roessler & Hasslacher Chemical Co.
- Spier, Harry F.
- Staley, H. F.
- Stockton-Abbott, Lyle
- Stone, Geo. C.
- Walton, H. K.
- Zeiller, Oscar F.

Niagara Falls
- Becket, Frederick M.
- Burdick, Percy W.
- The Carborundum Co.
- Fitzpatrick, John
- Harper, John L.
- Hawke, C. E.
- Kenyon, Spicer
- Linbarger, S. C.
- Taylor, R. F.
- Tone, Frank J.
- Walker, Prescott H.
- White, Ray H.

Nyack
- Goebel, J., Jr.

Peekskill
- Young, Everett T.

Port Jervis
- Foskett, John J.
- Gillinder, James
- Gillinder Bros.

Rochester
Bausch & Lomb Optical Co.
Chamberlain, C. H.
Chorman, O. I.
Geisinger, E. E.
Kurtz, John C.
Montgomery, Robert J.
The Pfaudler Co.
Scott, M. R.
Walcott, A. J.

Schenectady
Barringer, L. E.
Cermak, Frank
Creighton, E. E. F.
Treischel, Chester
Weber, August, Jr.

Solvay
Haaf, George

Syracuse
Cannan, Wm.
Haley, Mark A.
Kerr, W. B.
McGee, Earle N.
Milford, L. R.
Onondaga Pottery Co.
Pass, Richard Henry
Porter, J. Edward
Robineau, S. E.
Salisbury, Bert E.
Schram, Edward

Tottenville
Klinefelter, T. A.
Williams, George A.

Victor
Locke, F. M.
Reagan, F. H.

West New Brighton
Jones, Robert W.

Woodstock
Whitehead, Ralph R.

Yonkers
Reid, W. H.

NORTH CAROLINA

Badin
Fickes, W. M.

NORTH DAKOTA

Grand Forks
Cable, Margaret K.

Hebron
Weigel, Charles

OHIO

Akron
Deaver, L. A.
Knight, M. A.
Motz, W. H.

Barberton
Austin, Arthur Oswin

Bedford
McCormick, O. C.

Briggsdale
Cheney, M. B.

Bucyrus
Brown, Davis
Penfield, L. W.

Cambridge
Arbenz, Fred J. A.
Casey, Charles L.

Camp Sherman
Moore, E. J.

Canal Dover
Polen, Geo. A.

Canton
Cable, Davis A.
Canton Stamping & Enameling Co.
Hostetler, G. R.
Keplinger, Robert B.
Manion, L. W.
Stark Rolling Mill Co.
Taylor, Royal W.

Chippewa Lake
Cassady, Bertram L.

Cincinnati
Burt, S. G.
Dittmar, Carl
Kahn, Isaac
Koch, Chas. F.
Limberg, Frank
Metzner, Otto
Pfau, Charles
Robinson, Louis G.
Stewart, John G.

Cleveland
American Dressler Tunnel Kilns, Inc.
Baccus, Mrs. Julia F.
Blackburn, C. A.
Blair, Wm. P.
Brooks, Charles T.
Christie, J. M.
Clark, Wm. M.
CoVan, H. E.
Cowan, R. Guy
Crawford, George E.

Cushman, H. D.
Day, O. L.
Dougherty, Robert H.
Dressler, Conrad
Dressler, Philip
Forester, Herbert
Forsyth, J. H.
Fuller, Ralph L.
Giesey, V. A.
Gorton, Arthur F.
Greenough, M. B.
Harshaw, Fuller & Goodwin Co.
Hasslacher, George F.
Hays, George H.
Herron, James H.
Inman, G. E.
Landrum, R. D.
Morrow, Robert P.
Preston, F. C.
Radabaugh, N. B.
Rand, C. C.
Riblet, Bertha
Rixford, Guy L.
Roll, Edw. E.
Smith, Harry W.
Stone. Charles H., Jr.
Stowe, C. B.
Stowe, G. T.
Strommer, L. T.
Swift, George C.
Walden, A. S.
Weil, Edgar H.
Williams, C. W.

Columbus

Auld, F. Howard
Bachman, P. S.
Bole, G. A.
Callahan. H. D.
Curran, Hugh
Dean, Chas. A.
Douda, Henry W.
Dunbar, George S.
Ebinger, D. H., Jr.
Harrop, Carl B.
Henderson, H. B.
Henry, A. V.
Jenks, H. P.
Kraner, Hobart M.
Krehbiel, J. F.
Lord, N. W., Jr.
Lovejoy, Ellis
Merritt, L. M.
Ogden, Ellsworth
Orton, Edward, Jr.
Purdy, Ross C.
Reeb, H. E.
Richardon, W. D.
Scholes, S. R.
Schurecht, H. G.
Smith, Charles A.
Stout, Wilber
Stull, Ray T.
Tilton, Earl
Watkins, Ray T.
Watts, Arthur S.

Conneaut

Dunn, Frank B.
Dunn Wire Cut Lug Brick Co.

Coshocton

Raiff, David A.

Crooksville

Pitcock, Lawrence

Cuyahoga Falls

Brandt, George F.
Humphrey, Dwight E.

Dayton

Crume, Wm. H.
Geiger, Carl F.
Henry, Frank R.
Justice, Ithamar M.
Knapp, E. W.
McElroy, R. H.

East Liverpool

Ashbaugh, Charles C.
Brian, George
Brown, Lawrence H.
Cawood, Richard L.
The Colonial Co.
Cronin, W. Kress
Cunning, W. E.
Earl, Oliver N.
The Golding Sons Co.
Hall China Co.
Harker, H. N.
The Harker Pottery Co.
Homer-Laughlin China Co.
Irwin, Dewitt
Knowles, Taylor & Knowles Co.
Louthan, Wm. B.
The Louthan Manufacturing Co.
Manor, John M.
Mason, F. Q.
D. E. McNicol Pottery Co.
Muessig, C. Nick
Poole, Joshua
Potters Supply Co.
John H. Sant & Sons Co.
Sant, Richard C.
Sant, Thomas H.

Smith, H. Dan
Smith-Phillips China Co.
Standard Pottery Co.
Thomas, George W.
R. Thomas & Sons Co.
Thompson, Dale
Turnbull, Lance
Vodrey, Wm. E.
Vodrey Pottery Co.
Walker, Chas. H.
West End Pottery Co.

East Palestine
George, W. C.
W. S. George Pottery Co.

Elyria
Elyria Enameled Products Co.
Guthrie, Lee
King, Walter A.
Poste, Emerson P.
Rice, Bryan A.
Wigfield, C. L.

Findlay
Child, J. L.

Fostoria
Cramer, W. E.

Franklin
Montgomery, E. T.

Fredericksburg
Coxon, J. Frederick

Galion
Freese, H. H.

Haviland
Mumma, C. M.

Klondyke
Kraus, Louis P., Jr.

Lancaster
Frink Pyrometer Co.
Schurtz, D. D.
Sharp, Chester L.
Swinnerton, B. B.

Lima
Fenton, Harry W.

Logan
Cole, M. J.

Magnolia
Gunther, Franklin W.
Theobald, Erwin F.

Mansfield
Adams, Lewis A.
Barnes, T. R.

Massillon
Burt, F. M.
Massillon Stone and Fire Brick Co.

Middletown
American Rolling Mill Co.
Rupp, Edwin M.

Minerva
Cook, John H.
Owen China Co.

Newark
Young, C. B.
Zwermann, Theodore

New Philadelphia
DeWitt, Bert G.

New Straitsville
Blum, John W.

Niles
Niles Fire Brick Co.

Perrysburg
Brown, Edmund

Perrysville
Pyatt, Frank E.

Piqua
Hoehl, Joseph W.

Poland
Kanengeiser, Fred R.

Roseville
Brand, J. J. Fred

Rossford
Edward Ford Plate Glass Co.

Salem
Lamont, R. A., Jr.
Salem China Co.
Sebring, F. H., Jr.

Salineville
Larkins, Samuel B.

Sandusky
Frey, Wm. J.
Hare, Robert L.
Holmes, J. C.
Universal Clay Products Co.

Sebring
French China Co.
Gahris, Willard I.
Limoges China Co.
Saxon China Co.
Sebring, Charles L.
Sebring Pottery Co.
Sproat, Ira E.

Seville
Minton, C. R.

Springfield
Vance, Edward D.

Steubenville
Hollingsworth, C. M.
Steubenville Pottery Co.

Tiffin
Kalbfleisch, G. C.
Schory, Virgil S.
Tillotson, George S.

Tiltonville
Edwards, W. L.
Lindley, Jacob
McLaughlin, John

Toledo
Brownlee, Wm. K.
Brownlee, Wm. L.
Buckeye Clay Pot Co.
Corl, Robert M.
Fisher, E. E.
Garrod, Fred B.
Hess, Henry W.
Minehart, A. G.
Nolan, C. J.
Richardson, E. A.
Robinson, J. D.
Zopfi, Albert S.

Toronto
Hartford, Frank M.

Uhrichsville
Brower, Fred W.
Myers, Scott P.

Wellsville
Blewett, J. B.
East Liverpool Potteries Co.
Ewing, R. F.
Hibbins, Thomas A.
Martz, Joseph A.
Purinton, Bernard S.

West Lafayette
Shaw, Lucian
Strong, Thomas L.

Willoughby
Rentschler, M. J.

Zanesville
American Encaustic Tiling Co.
Brown, L. K.
Brush, George S.
Burton, R. C.
Carling, John P.
Crew, H. F.
Evans, A. W.
Fraunfelter, Chas. D.
Gonder, Lawton G.
Grant, Frederick J.
Hagar, Donald
Herrold, R. P.
Krause, George
Lillibridge, H. D.
Miller, Emerson R.
McCoy, William
Mosiac Tile Co.
Niblock, Chas.
Ohio Pottery Co.
Owens, J. B.
Pence, F. K.
Reed, Adam
Rhead, Frederick H.
Rhead, Mrs. Frederick H
Rhead, Harry W.
Schmid, A. F.
Shultz, J. Emmet
Snider, Paul C.
Tefft, T. Dwight
Trifonoff, Boris
Weller, Samuel A.
Whitmer, J. D.
Young, Russell T.

Youngstown
Aubrey, Arthur J.

OKLAHOMA

Checotah
Harrell, E. R.

Oklahoma City
Harris, Marshall W.

Sapulpa
Bartlett, Edward E.
Brenner, R. F.

OREGON

Forest Grove
Martin, Earle V.

Portland
Pohs, Frank J.
Portland Stove Works
Smith, A. M.
Wethey, Arthur Harvey, Jr.
Williams, Ira A.

PENNSYLVANIA

Allentown
Hersh, Lewis E.

Arnold
Forman, L. P.
Sewell, Sidney I.
Williams, Warren S.

Beaver
Hice, Richard R.

Beaver Falls
Beaver Falls Art Tile Co.
Bently, Louis L.
Hardesty, B. D.
Hunt, Frank S.
Mayer, A. E.
Richardson, Ernest
Sladek, George E.
Walker, Francis W.
Walker, Francis W., Jr.

Bellefonte
Harvey, Ives L.

Belle Vernon
Weaver, James P.

Blandburg
Caruthers, Raymond G.

Brookville
Bloxsom, John J.
Myers, Elmer E.

Butler
Troutman, Frank E.

Charleroi
Jacobs, W. M.
Stoneman, Wm. N.
Wright, J. W.

Claysburg
Kurtz, Thomas N.

Clearfield
Paterson, Alexander

Columbia
Russel, John W.

Creighton
Cox, S. Frank
Fulton, C. E.
Gelstharp, Frederick
Koupal, Walter G.
Lardin, R. H.
Linder, C. S.
Minton, G. Z.
Truby, Harry A.

Crum Lynne
Stephani, Wm. J.
Stull, Jos.

Curwensville
Crescent Refractories Co.
McKinley, J. M.

Derry
Emrick, W. A.
Fritz, E. H.
Pittsburgh High Voltage Insulator Co.

Dickson City
Early, Joseph W.

DuBois
Jackson, H. W.

Dunbar
Greenwood, G. W.

Easton
Brian, Chas.
Hart, Edward

Fallston
Rainey, Lloyd B.

Ford City
Panchot, L. D.

Jeanette
Smith, Maurice A.

Kittanning
George, J. S.
Martin, S. C.

Kushequa
Blair, J. A.

Lancaster
Horning, Roy A.

Lansdowne
Davis, John B.

Latrobe
Ward, J. W.

Lewistown
Lord, F. G.
Pennsylvania Pulverizing Co.
Woods, Wm. J.

Monaca
Tait, Howard J.

Mt. Union
Harvey, F. A.

Natrona
Darlington, Homer T.

New Bethlehem
Luke, Chas. H.

New Brighton
McDanel, Walter W.
Smith, Perry A.

New Castle
Brain, George
Hornung, Martin R.
Kirk, Charles J.
Kirk, H. S.
Mellor, F. G.
Morris, George D.
Smith, James M.

New Eagle
VanMoore, A. L.

New Hope
Garve, T. W.

Norristown

Sheppard, Mark

Orviston

Harvey, J. Ellis

Palmerton

Ashman, Alfred O.
Breyer, Frank G.
Holstein, L. S.

Paxtonville

Fowler, William E.

Philadelphia

Abrasive Co.
Applegate, D. H., Jr.
Ayres, Elwood B.
Bacon, Chas. C.
Borkey, J. H.
Brown, Richard P.
Conkling, Samuel O.
Fulweiler, Walter H.
Galloway, Walter B.
Gibbs, Arthur E.
Goheen, John P.
Griffith, R. E.
Hall, Clarence A.
Hibbs, Jos. S.
Hill, E. C.
Knollman, H. J.
Moore, H. W.
Pettinos, Geo. F.
Philadelphia Drying Machinery Co.
Plusch, H. A.
Ritschy, Donald P.
Saunders, Wm. E.
Stanger, Frederick
Thwing, C. B.
Vane, A. S.
Wood, C. P.
Worth, S. Harry

Pittsburgh

Amsler, Walter O.
Babcock, M. G.
Bacon, Raymond F.
Berkey, Paul L.
Blake, A. E.
Boudreau, James C.
Buck, D. M.
Buckley, J. L.
Chandler, A. H.
Chatham, C. W.
Christman, C. E.
Clayter, Frederic C.
Crawford, J. L.
Cruikshank, J. W.
Denk, F. J.
Dixon, Henry L.
H. L. Dixon Co.
Donahoe, Frederic W.
Elledge, H. G.
Emminger, Thos. F.
Farren, Mabel C.
Ferguson, Robert F.
Fettke, Chas. R.
Gilmore, R. B.
Good, Harry N.
Goodman, A. H.
Gray, Arthur E.
Greaves-Walker, A. F.
Guenther, Emil B.
Hammer, John M.
Hansen, J. E.
Harbison-Walker Refractories Co.
Hepplewhite, J. W.
Houser, A. T.
Howe, Raymond M.
Hower, H. S.
Hunt, Marsden H.
Johnston Brokerage Co.
Kier, Samuel M.
Kier Fire Brick Co.
Kimes, A. W.
Lyon, P. W.
McDowell, J. S.
McLain Fire Brick Co.
Macbeth-Evans Glass Co.
Miller, Julius J.
Mossman, P. B.
National Fireproofing Co.
Offill, Paul M.
Ogale, G. P.
O'Leary, T. A.
Pennsylvania Salt Mfg. Co.
Peregrine, C. R.
Phoenix Glass Co.
Pierce, Robert H. H.
Pittsburgh Plate Glass Co.
Reed, H. M.
Robertson, H. S.
Rochow, W. F.
Sauereisen, C. Fred
Seaver, Kenneth
Silverman, Alexander
Smyser, Albert E.
Standard Sanitary Mfg. Co.
Stewart, Andrew H.
Sutton, Willard J.
Tillotson, E. W.
Unger, J. S.
United States Glass Co.
Varshnei, B. D.
Vitro Manufacturing Co.

Vogt, C. C.
Vollkommer, Josef
Wenning, W. F.
Willetts, H. G.
Winkleman, E. J.

Point Marion
L. J. Houze Convex Glass Co.

Reading
Hettinger, Edwin L.
Seasholtz, J. M.

Royersford
Wells, R. D.

Scranton
Bour, Laurence J.

State College
Moore, Elwood S.

St. Marys
Grant, W. Henry
Ramsay, J. D.

Tarentum
Jones, Richard E.
Morris, Paul R.
Parkinson, S. C.

Tyrone
Hepler, I. F.

Uniontown
Nye, C. P.

Vanport
Hall, Herman A.

Washington
Algeo, A. M.
Brett, R. C.
Duval D'Adrian, A. L.
Findlay Clay Pot Co.
Flint, Francis C.
Frazier, C. E.
Lambie, J. M.
Lloyd, A.
Ross, Donald W.
Thompson, Harry M.

Watsontown
Owens, Francis T.
Tefft, C. Forrest

Wilkinsburg
Bell, M. L.
Coe, John H.

RHODE ISLAND

Central Falls
Kline, Z. C.

Providence
American Emery Wheel Works
Harding, Browne

SOUTH DAKOTA

Brookings
Gernon, Ursula F.

TENNESSEE

Chattanooga
Mahoney, W. T.
Patten, D. M.

Nashville
W. G. Bush & Co.

Puryear
Harker, O. A., Jr.

Whitlock
Mandle, Sidney

TEXAS

Dallas
Fraser, W. B.
Ryan, J. J.

Denton
Lacy, Miss Mattie Lee

Fort Worth
Porter, F. B.
Smith, R. G.

McQueeney
Potts, Amos

UTAH

Murray
Myers, Chas. H.

Salt Lake City
Ellerbeck, Wm. L.
A. A. Garrison

VIRGINIA

Roseland
Taylor, R. P.

WASHINGTON

Auburn
MacMichael, P. S.
Zwerner, Carl G.

Chewelah
Dolman, C. D.

Clayton
Davies, J. L.

Renton
Cake, B. F.
Rogers, Gregory L.

Seattle
Geijsbeek, Samuel
Heath, Fred T.
Keenan, John Francis
Martin, Leonard A.
Wilson, Hewitt

Spokane
Bryan, M. L.
Goodner, Ernest F.
Oudin, Chas. P.
Washington Brick Lime and Sewer Pipe Co.

Taylor
Lemley, W. E.

WEST VIRGINIA

Berkeley Springs
Carman, C. F.

Charleston
Brown, Wilbur F.
Henshaw, S. B.

Chester
Smith, Will L., Jr.
The Taylor Smith and Taylor Co.

Clarksburg
Bracken, Lloyd
Payne, A. R.

Fairmont
Arbogast, F. J.
Monongah Glass Co.
Shively, R. R.
Wood, O. A.

Follansbee
Jefferson Glass Co.

Grafton
Reddick, W. L.

Kenova
Axford, Vincent
Beeken, L. L.
Johnston, Robert M.
Kirkpatrick, F. A.
McVay, T. M.
Nagle, J. A.
Wood, A. T.

Moundsville
Blair, Marion W.
Sanders, John W.

New Cumberland
Goodwin, Herbert
Koos, E. K.

Newell
Bleininger, A. V.
Edwin M. Knowles China Co.

Parkersburg
Anderson, Geo. O.
Davis, S. E.
Milligan, Frank W.

Wheeling
Franzheim, C. Mertz
Jackson, C. Edward
Laughlin, Samuel O.
Malkin, Wm. R.
Swalm, P. H.
Warwick China Co.

WISCONSIN

Beaver Dam
Rogers, Frederick W.

Kohler
Kohler, W. J.

Madison
Storey, O. W.

Milwaukee
Dings Magnetic Separator Co.
Layman, Frank E.
A. J. Lindemann & Hoverson Co.
Manson, Mahlon E.

Sheboygan
Riess, Dewitt F.
Vollrath, W. J.

AUSTRALIA

Mitcham, Victoria
Walker, E. E.

AUSTRIA

Radenthein, Kaerntern
Erdmann, K.

BELGIUM

Brussels
Musiol, Charles

CANADA

Aldershot, Ontario
Dingledine, H. F.

Cooksville, Ontario
Cote, A. U.

Cowansville, Quebec
Lauer, Frank E.

Hamilton, Ontario
Emery, George
Goddard, W. T.
Harvey, George R.
Meldrum, A. T. S. C.

Hartington, Ontario
Gardner, William

Hespeler, Ontario
Clare, H. L.

Kingston, Canada
Townsend, Everett
Glass, L. G.

London, Ontario
Munroe, L. J.

Montreal, Quebec
Cole, G. Percy
Davidson, T. R.
Hesler, N. A.

Moose Jaw, Saskatchewan
Love, Herbert G.

Ottawa, Ontario
Cole, L. Heber
Davis, N. B.
Keele, J.

Saskatoon, Saskatchewan
Worcester, W. G.

Sault Ste. Marie, Ontario
Knote, J. M.

St. John, New Brunswick
Foley, Fenwick D.

St. Laurent, Quebec
Brown, Thomas G.

Thorold, Ontario
Orrell, John

Toronto, Ontario
Bush, Hiram T.
Corrigan, F. S.
Gaby, F. A.
Gibson, M. F.
Groocock, Alice
Gunn, James
Segsworth, R. F.
Segsworth, W. E.
Turner, Eric W.

CHINA

Canton
Laird, Clinton N.

Hankow Extension
Wang, C. Y.

Shanghai
Chu, Kea Hin
Leibson, J. S.
Lin, C. C.
Page, H. E.
Ling, S. C.

DENMARK

Copenhagen
Jacobsen, Carl
Paulsen, Carl A.

ENGLAND

Accrington
Hayhurst, Walter

Acomb
Snowdon, William C.

Bolton
Gass, George Pool

Brierley Hill
Cronshaw, H. B.

Chatteris
Curtis, Algernon Lewin

Fingringhoe
Hope, Herford

Halifax
Parkinson, Caleb

Knottingley
Gregg, Henry

Leeds
Barrett, Maurice
Cobb, John W.
Lax, Frederick
Lax, Thomas

Lesbury
Pitt, H. H.

Liverpool
Bateson, H. A.

London
Frink, R. L.
Speir, Chas. W.
Travers, Morris W.

Loughborough
Hodson, G. A.

Meltham
Gardner, W. J.

Rugby
Gatecliff, John

Sheffield
Holland, Job
Rees, W. J.
Searle, A. B.
Turner, W. E. S.

Stoke-on-Trent
Cleverly, Wm. B. Jr.
Hawley, W. S.
Mellor, J. W.
Ramsden, C. E.
Scott, Alex
Shaluvalia, Dogar Singh

Stourbridge
Thomas, Chas. W.

Teddington
Coad Pryor, E. A.

Wareham
Pike, Leonard G.

Whitley Bay
Skidmore, G. R. J.

Burton-on-Trent
Tooth, W. E.

Worcester
Solon, G. C.
White, G. N.

FRANCE

Aigues Mortes (Gard)
Saxton, Clement

Aniche (Nord)
Dufour, G. F.

Ivry (Seine)
Bodin, Victor

Ivry-Port (Seine)
Sailly, Paul

Limoges
DeLuze, Henri
Haviland, John

Paris
Bigot, A.
Boudouard, O.
Gentil, E.
Van Overstraeten, Jean

Villejuif (Seine)
Berland, Louis

GERMANY

Heidelberg
Havas, A. B.

Reisholz Bei Dusseldorf
Coulter, Allen S.

Selb, Bayern
Singer, Felix

Wesseling bei Koeln
Griffin, Carl

INDIA

Calcutta
Bird & Co.
Deb, S.
Andrew Yule & Co., Ltd.

Poona City
Kelkar, G. D.

JAPAN

Amagasaki City
Ide, Kiyoshi

Fukuoka
Aoki, S.

Hodogaya
Takahashi, K.

Kawasaki
Satoh, Shinzo

Kyoto
Fujioka, Koji
Kitamura, Y.
Yoshioka, Tosaku

Kysushu
Momoki, Saburo

Nagoya
Okura, K.

Okayamaken
Kato, Mitsu

Omuta
Saito, Hachiro
Tatsumi, Eiichi

Osaka
Kawai, Kozo
Niemura, Nobutaro
Yamamoto, Tamesburo

Shigaken
Kurahashi, T.

Tokyo
Kondo, S.
Misumi, Aizo
Shibata, R.
Umeda, Otogoro
Yamada, Sanjiro

MANCHURIA

Dairen
Hirano, Kosuke
Murai, S.

NORWAY

Borgestad
Knudsen, Rolf

Kristiania
Andersen, Olaf

NOVA SCOTIA

Sydney
Mackie, I. C

SCOTLAND

Bonnybridge
Stein, Alan

Barrhead
Shanks, Douglas
Shanks, Ronald J.

Edinburgh
Marson, Percival
Wyse, Henry T.

SOUTH AMERICA

Buenos Aires, Argentine
Bianchedi, Romulo

Cerro de Pasco, Peru
Cuthbertson, M. R.

Palantelen
Hoursouripe, J.

Rancagua, Chile
Ward, S. Paul

SPAIN

Barcelona
Villalta, John F. R.

SWEDEN

Helsingborg
Cronquist, Gustav Wson.

Hoganas
Sieurin, Emil

Kosta
Fogelberg, Sven

Stockholm
Fredriksson, Nils
Odelberg, A. W.